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REVIEW AND RECOMMENDATIONS FOR THE INTERAGENCY SHIP STRUCTURE C--ETC(U)  
MAR 78 O H OAKLEY, M D BURKHART, J N CORDEA

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Review and Recommendations  
for the  
Interagency  
Ship Structure Committee's  
Fiscal 1979 Research Program

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Maritime Transportation Research Board

Commission on Sociotechnical Systems

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⑥ REVIEW AND RECOMMENDATIONS  
for the  
INTERAGENCY  
SHIP STRUCTURE COMMITTEE'S  
FISCAL 1979 RESEARCH PROGRAM,

⑨ Final rept.,

⑩ O. H. / Oakley,  
M. D. / Burkhardt,  
J. N. / Cordea,  
D. P. / Courtsal  
E. S. / Dillon

A Report Prepared  
by the  
SHIP RESEARCH COMMITTEE  
of the

Maritime Transportation Research Board  
Commission on Sociotechnical Systems  
National Research Council ✓

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⑫ 111p.

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NOTICE: The project that is the subject of this report was approved by the Governing Board of the National Research Council, whose members are drawn from the Councils of the National Academy of Sciences, the National Academy of Engineering, and the Institute of Medicine. The members of the Committee responsible for the report were chosen for their special competences and with regard for appropriate balance.

This report has been reviewed by a group other than the authors according to procedures approved by a Report Review Committee consisting of members of the National Academy of Sciences, the National Academy of Engineering, and the Institute of Medicine.

\*\*\*\*\*

This report was prepared for the interagency Ship Structure Committee, consisting of representatives from the Military Sealift Command, the U.S. Coast Guard, the Naval Sea Systems Command, the Maritime Administration, and the American Bureau of Shipping, and is submitted to the Commandant, U.S. Coast Guard, under provisions of Contract DOT-CG-80356-A between the National Academy of Sciences and the Commandant, U.S. Coast Guard, acting for the Ship Structure Committee.

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### ABSTRACT

The Ship Research Committee (SRC) of the National Research Council provides technical services covering program recommendations, proposal evaluations, and project advice to the interagency Ship Structure Committee (SSC), composed of representatives from the U.S. Coast Guard, Naval Sea Systems Command, Military Sealift Command, Maritime Administration, and the American Bureau of Shipping. This arrangement, established since 1946, requires continuing interaction among the SRC, the SSC, the contracting agency and the project investigators to assure an effective program to improve ship hull structures through an extension of knowledge of materials, fabrication methods, static and dynamic loading and response, and methods of analysis and design. This report contains the Ship Research Committee's recommended research program for five years, FY 1978 - 1982, with 14 specific prospectuses from which to select projects for FY 1979. Also included is a brief review of 26 active and 6 recently completed projects.

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## INTRODUCTION

### Organizational and Administrative Matters

#### Establishment of Committees

Since 1946, the National Research Council's Ship Research Committee (SRC) and its predecessors have been rendering technical services to the interagency Ship Structure Committee (SSC) in developing a research program (sponsored by the SSC and funded collectively by its member agencies) to determine how ship structures can be improved for greater safety and better performance without an adverse effect on the economy.

The SSC was established in 1946 upon recommendation of a Board of Investigation, convened by order of the Secretary of the Navy, to inquire into the design and methods of construction of welded steel merchant vessels. As that investigation was brought to a close, several unfinished studies and a list of worthy items for future investigation remained. Thus, the Board recommended that a continuing organization be established to formulate and coordinate research in matters pertaining to ship structure. The chart, Figure 1, which follows, shows the relationship

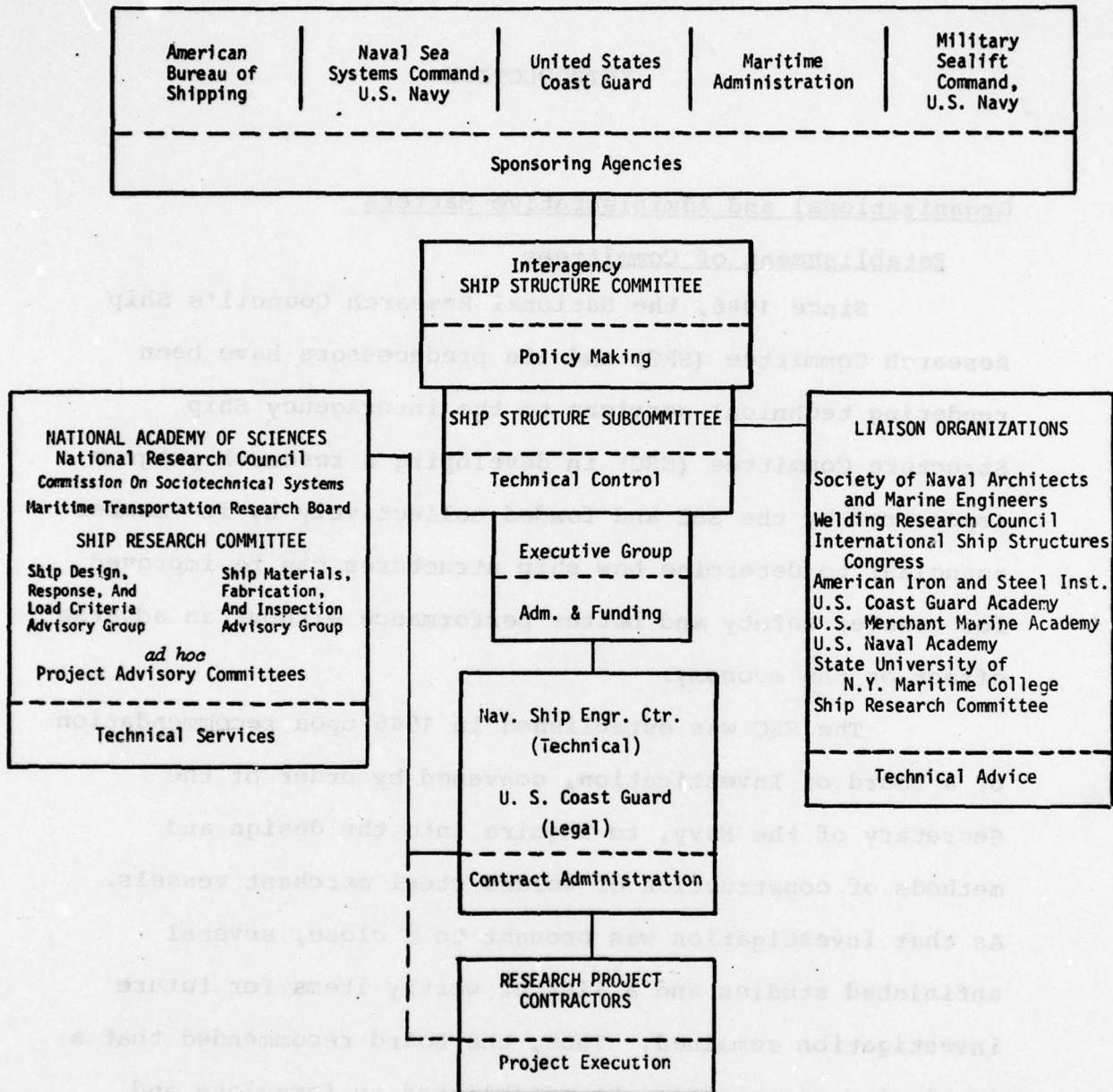


FIG. 1. - SHIP STRUCTURE COMMITTEE ORGANIZATION CHART

of the various organizational entities involved in the work of the SSC.

Committee Composition and Responsibilities

The SSC is composed of a senior official from the U.S. Coast Guard, Naval Sea Systems Command, Military Sealift Command, Maritime Administration, and American Bureau of Shipping. In 1977, the U.S. Geological Survey (USGS), which is responsible for personnel, safety, and environment associated with the offshore oil and mining industry, agreed to participate as an observer for the balance of the 1978 fiscal year with the intent of becoming a permanent member in fiscal 1979.

The SSC formulates policy and approves program plans, and provides financial support through its member agencies for the research program. In 1977, the USGS contributed to the support of the FY 1978 program.

Four representatives from different divisions within each agency meet periodically as a Ship Structure Committee (SSSC) to assure achievement of the program goals and to evaluate the results in terms of ship structural design, construction, and operation.

Members for the SRC and its advisory groups are selected for their competence, experience, and expertise in relevant areas from academic, governmental, and industrial sources. The members serve as individuals contributing their personal knowledge and judgements and not as representatives of any organization in which they are

employed or with which they may be associated. Their responsibilities to the SSC are to assist in setting technical objectives; define research projects; recommend research priorities; evaluate proposals, review the active projects, including progress and final reports, and prepare summaries of related research work.

#### Research Program Development

It has become standard procedure for each organization represented on the SSC to prepare a memorandum report each year on current research needs and suggestions for research projects. Copies of these memorandum reports are transmitted to the SRC. In 1976, and again in 1977, this procedure was enhanced by holding a joint meeting of members of the SRC, SSSC, and the Hull Structure Committee of the Society of Naval Architects and Marine Engineers to review the reports. The papers were made available in advance of the meeting so that attendees could prepare questions. In addition, the member agencies also presented status reports on the pertinent structural research work under way in their respective agencies. This process was scrutinized during the SSSC meeting in October, 1977, and an ad hoc committee was appointed to review the practice and to recommend how it could be made more productive.

#### Project Development

The suggestions in these reports, those generated within the SRC and its Advisory Groups, and those obtained from other sources are carefully studied for applicability

to the SSC research program in terms of need, immediacy, program continuity, and likelihood of successful and meaningful completion. A prospectus is drafted by the appropriate SRC Advisory Group for each of the research projects that is considered worthy of SSC support and included in an annual report to the SSC. The SSC determines which projects will be supported. Requests for proposals are prepared and put out through a cooperative effort between the Naval Ship Engineering Center (NAVSEC), which provides technical contract administrative support services, and the USCG which handles the actual business of contracting. The prospectus becomes a part of a Request for Proposal (RFP) and subsequently a part of the contract document. The RFP's go to private research laboratories, universities, shipyards, and other organizations and are advertised in the Commerce Business Daily.

#### Proposal Evaluation Procedure

An organization that is interested in doing work submits a proposal and an estimated cost. The USCG Contracting Office removes the cost data and transmits the technical data in the proposal to the SRC for technical evaluation and review, with the admonition that no information contained in the proposal or the identity of the offerors be made available to the public or to anyone within the Government prior to the Coast Guard making the award.

After the SRC Executive Secretary has verified that no SRC or advisory group member or affiliated company is

represented in the proposals, the SRC chairman selects an ad hoc proposal evaluation committee. Any committee or advisory group member with a vested interest in the proposal is excluded from the ad hoc evaluation committee. This important step avoids conflict of interest. The evaluation committee generally consists of the Chairmen of the SRC and the pertinent advisory group, two or three other members from either the advisory group or the SRC, the Secretary of the SSC, the Contract Officer's representative, and frequently one or two SSC liaison members.

The proposals are numerically evaluated for the analysis of the problem, the proposed solution, the assessment of the scope of the effort, and the adequacy of the organization and personnel.

After the evaluation committee judges the technical merit of the proposals, ranks them, and comments on any shortcomings, the USCG Contracting Officer forwards the technical evaluation and cost data to the SSC. The SSC considers the proposals together with the technical evaluation and costs, and sends its recommendations to the Contracting Officer, who, following routine procurement practices, then awards a contract.

#### Annual Report Summary

SRC-SSC research activities during the current year are covered in the annual report by status and progress reports on active and pending projects and synoptic reports on research projects that have been or probably will be

completed during the current year. The annual report also includes recommendations to the SSC for research to be funded and started during the ensuing fiscal year. The numbering system for projects has been modified as a result of the October 1977 SSSC meeting to avoid confusion with the numbering system for SSC reports. Since both the SR project number series and the SSC report number series are in the two hundreds, the likelihood of confusion is apparent. It was therefore agreed to change the SR project numbering system by simply adding 1000 to the SR numbers; e.g., SR-255 now becomes SR-1255. The new system is used in this annual report for the first time.

This, the latest in the series of annual reports, covers research activities during Fiscal Year 1978 and sets forth recommendations for the SSC's Fiscal Year 1979 Research Program. This year, as in certain other previous years, the report outlines a five-year research planning program, which the SRC hereby recommends for SSC consideration. As this report is directed to a very small readership in close contact with the evolving programs, no attempt has been made to show how the planned projects relate to the projects done in the formative years of the SSC. However, there are two historical documents that provide this background: namely, Twenty Years of Research Under the Ship Structure Committee by S. R. Heller, Jr., A. R. Lytle, R. Nielson, Jr., and J. Vasta, 1967, SSC-182, NTIS AD 663677, and

Third Decade of Research Under the Ship Structure Committee

by E. A. Chazal, J. E. Goldberg, J. J. Nachtsheim, R. W. Rumke, and A. B. Stavovy, 1976, SSC-252, NTIS AD-A021290.

Five-Year Research Program Plan

The five-year research planning program builds upon current activities, placing them in perspective with contemplated work in various project areas during the next four years. The project areas have been classified under six headings which are essentially consistent with the research goals of the SSC.

It is intended that the program be dynamic and flexible in that it can be modified and redirected to be responsive to changing circumstances.

Figure 2 is a flow chart showing how the elements of the five-year plan proposed by the SRC support the SSC's primary objective: namely, to provide information that will assist the U.S. shipbuilding industry in designing and building safer, more cost effective, and more easily maintained ship structures by exploiting existing and potential competitive advantage through the advancement of technology. The five-year plan has been developed for each of the stated and implied contributing technical goals:

- Research Plan Development
- Loads Criteria
- Response Criteria
- Materials Criteria
- Fabrication Techniques
- Determination of Success/Failure Criteria  
(Reliability)
- Design Methods

Work in each of these areas will include adequate verification procedures to assure that sound recommendations are made. The thrust will be to expand, as necessary, the existing base of knowledge in each area, to result in design methods, fabrication procedures, and materials that will produce safer and more efficient ships. Table I represents the five-year plan in each area.

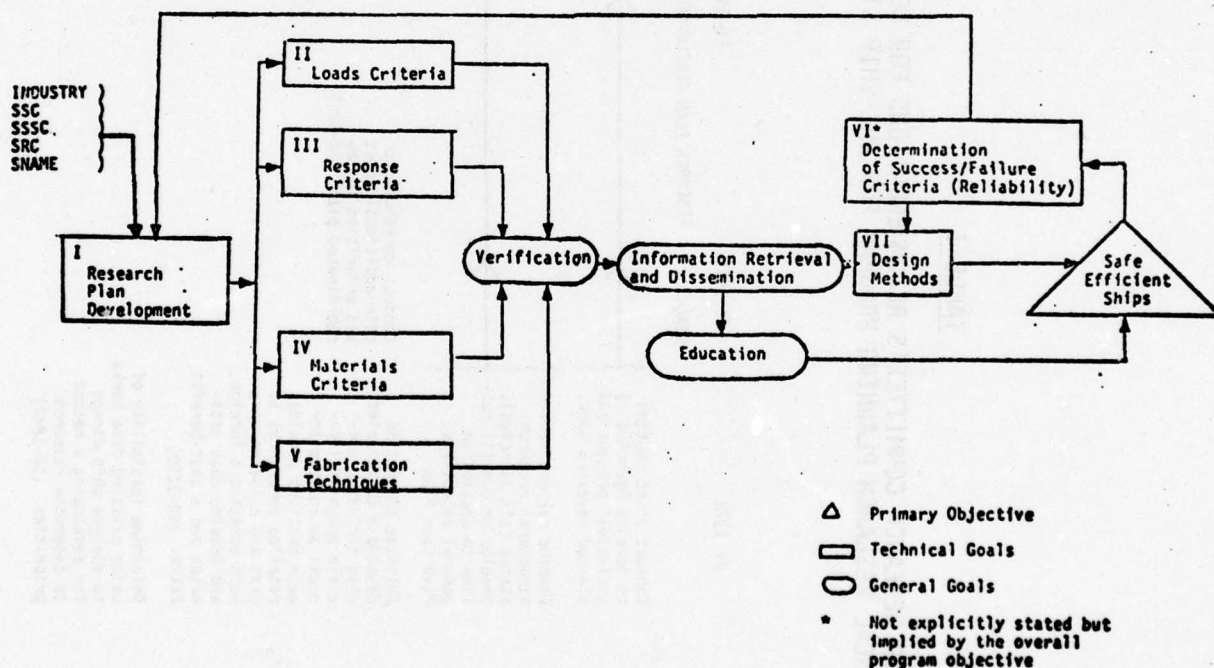


FIG. 2. - FLOW DIAGRAM FOR SHIP STRUCTURE COMMITTEE'S GOALS

TABLE I

## SHIP RESEARCH COMMITTEE'S RECOMMENDATIONS FOR CONTINUING FIVE-YEAR FISCAL RESEARCH PLANNING PROGRAM FOR THE SHIP STRUCTURE COMMITTEE.

PROJECT AREA	FY 1978	FY 1979	FY 1980	FY 1981	FY 1982
Overall research planning studies	GOAL: I - RESEARCH PLAN DEVELOPMENT				
	Conduct joint meeting to develop Agencies' & Societies' present and planned research work.				
	Examine current marine structural research status (all agencies). Develop an overall outline to accomplish general objectives. Five Year Plan				
	Initiate project to develop a coordinated plan including specific proposed technical approaches for each section; provide detailed references to past and existing work both domestic & foreign, and provide cost estimates and a cost-benefit ratio. (SR-1259)	Conduct workshops to gain additional input and priorities to the coordinated plan. (SR-1259)			
	Determine feasibility of using existing data banks to analyze ship damage for developing a method to determine research priorities. (SR-1247)	(Commence following research plan.)			

TABLE I

PROJECT AREA	FY 1978	FY 1979	FY 1980	FY 1981	FY 1982
	GOAL: II - LOADS CRITERIA				
Static/Quasi Static Thermal (Diurnal, Cryogenic, Hot) Cargo, Ballast, Fuel, Cargo Distribution, Light Weight of Ship, Ship's Induced Wave, Ice, Impact, Crushing.	Complete project SR-1227 to compile and analyze several loading variables for three different types of ships.	Begin program to obtain static/quasi static data for typical ships. (79-14)	Complete data collection program.	Prepare Design Load Profiles. Recommend modifications to Design Criteria.	
		Begin project to review literature, ship operations, and ice histories of navigable waterways for ice loadings on ships. Compare with present ice strengthening of ships. Indicate where additional information required. (79-6)	Review ice project results and develop plan to obtain necessary data.	Carry out ice loading plan.	
Dynamic Cargo Liquid, Sloshing, Dry, Shifting Load, Pumping Problems, Mobile Cargo (Wheeled Vehicles)	SR-1251 is to survey test, analyze, and develop liquid dynamic load criteria in slack cargo tanks for LNG carriers.	Review SR-1251 results.	Review & correlate current model and full-scale non LNG liquid slosh data. Conduct model tests to complete dictation of wall response correlations for various fill depth, pressure. Recommend geometry, and excitation parameters.	Evaluate significance of impulsive slosh loads in full-scale liquid tanks. Develop prediction of wall response to impulsive slosh pressure. Recommend design criteria for tank walls.	Develop general purpose curves and tables for use in design of liquid cargo tanks.

TABLE I

PROJECT AREA	FY 1978	FY 1979	FY 1980	FY 1981	FY 1982
Dynamic Cargo (Cont.)			Review & categorize types of shifting cargo loads, and establish priority of dynamic load problems. Develop plan for analysis of high priority items.	Conduct analyses and/or tests to establish dynamic loads and corresponding structural responses to shifting cargo under typical operational conditions.	Develop curves and tables for ready use in design for dynamic loads due to shifting cargo.
Propeller-Induced	Complete survey and evaluate present methods to predict propeller-induced vibration in hull structural elements, including skewed propellers. (SR-1240)	Review SR-1240 results.			
			Study results and recommendations from 1978 Vibration Symposium.	Identify and describe existing analytical methods for predicting wake fields.	Develop correlation of wake field studies.
				Identify and describe analytical methods for predicting magnitude & nature of propeller cavitation.	
				Develop program, and conduct tests to validate cavitation study results.	Evaluate cavitation studies and produce guide.
				Consider effects from propeller emergence.	

TABLE I

PROJECT AREA	FY 1978	FY 1979	FY 1980	FY 1981	FY 1982
Propeller-Induced (Cont.)					
Wave-Induced Wave Records/Spectra Local Ship Wave In- strumentation Slam- ming, Green Water Steady State.	Complete report of full-scale slam instrumentation package. (SR-1235)	Review USCG Great Lakes project utilizing portion of full-scale slam instrumentation package.	Develop prospectus for full-scale slam instru- mentation and wave- meter data collection.	Develop test plan to measure propeller emergence effects.	Initiate test plan to measure propeller emergence effects.
				Analysis of impact pressure and velocity. Correlate trials data with model experiments and theory.	Develop technology to predict impact loads for ship design consideration.
				Conduct full-scale trial slamming & bow-flare impact data using the instrumentation developed under Project SR-1235.	
					Develop a method to statistically estimate the combined wave-induced bending and torsional loads necessary to perform structural failure analysis.
	Formulate a plan for obtaining needed world-wide ocean wave data in suitably uniform format from various U.S. & foreign government agencies & non-governmental groups.	Review status of wave data collection and prospects for application in design.	Collect & analyze wave information at locations of interest along trade routes by using reliable wave recorder.	Continue collection and analysis of wave information and develop long-term wave statistics necessary for fatigue failure analysis.	
	Complete SR-1221 Correlation and Verification of Wave meter data from SL-7.				

TABLE I

PROJECT AREA	FY 1978	FY 1979	FY 1980	FY 1981	FY 1982
	GOAL: II - LOADS CRITERIA (CONT.)				
Collision and Stranding and Dry Docking Loads.		Develop dry-docking & low-energy stranding loads, and analysis program. (79-9)	Complete and review dry-docking program results.	Establish the common technologies applicable to both ship collision & stranding problems.	Consider adding wave loads on stranded ships.
	Complete SR-1237 to evaluate existing low-energy collision damage theories and possible use and limitations.	Review SR-1237 results.	Develop prospectus for computer simulations of low-energy ship collision dynamics for various collision scenarios.	Develop and perform full-scale or model tests to verify computer simulations and to establish important collision phenomena.	Complete test program.
	Monitor collision and stranding research & issue status reports. (SR-246)	Continue surveillance of ship collision/stranding research studies. (SR-1246)	Continue surveillance of ship collision/stranding research studies. (SR-1246)		
	GOAL: III - RESPONSE CRITERIA				
Vibrations Analysis & Prediction, Steady State (Springing, Bending, Torsion), Transient, (Whip- ping), Acoustic Transmission Measurement/Verif- ication.	Evaluate proposals to collect hull structural damping data. (SR-1261)	Collect & evaluate ship structural damping data to extend design. (SR-1261)	Review SR-1261 and indicate test program extensions.		

TABLE I

PROJECT AREA	FY 1978	FY 1979	FY 1980	FY 1981	FY 1982
	GOAL: III - RESPONSE CRITERIA				
Vibrations (Cont.)					
		Begin analysis and measurement on different ship propulsion shafting systems in order to prepare a set of guidelines for the analysis of thrust bearing foundation stiffness. (Research Project M-8 from SNAME Panel M-20).	Complete analysis and preparation of Thrust Bearing Foundation Stiffness Guide.		
Stress/Deformation Analysis & Prediction Measurement/Verification, Steady State, Transient, Static, Thermal	Verification of calculated stress as compared to full-scale measured values. (SR-1236).	Continue stress verification program.	Start project to complete comparisons of ship motions and load computer programs with full-scale SL-7 data.		
		Initiate pressure distribution model tests in waves to determine necessary strength of local structure (79-11).	Continue pressure distribution model tests. Use Webb computer program to calculate pressure distribution corresponding to model tests	Compare model and computer results for pressure distribution.	
	Continue collection and reduction of SL-7 scratch-gage data (SR-1215 and SR-1245)	Continue SL-7 scratch-gage data collection. (SR-1215).	Continue scratch-gage extreme stress data collection. (SR-1215).	Continue scratch-gage extreme stress data collection on SL-7, if necessary, or gather data on ships of another class.	Scratch-gage extreme stress data collection.
		Compare mechanical scratch-gage data with electronic strain gage data aboard SL-7. (79-4).			
		Establish deflection criteria for ship in relation to main machinery alignment tolerances. (79-3)	Fabricate and test large-scale models of hull elements to verify criteria.		

TABLE I

PROJECT AREA	FY 1978	FY 1979	FY 1980	FY 1981	FY 1982
	GOAL: III - RESPONSE CRITERIA (CONT.)				
Motions (Rigid Body) Analysis/Prediction Measurement/Veri- fication motions in Following Seas, Non- conventional Forms, Multi-hull, Hydro- foils, Submersibles.				Prediction of non- linear roll response and roll stabilization in irregular seas.	Modify seakeeping ship loading programs to include non- linear roll response.

## GOAL: IV - MATERIALS CRITERIA

Materials Trade-Off  
Concrete, Aluminum  
Composites.

Review results  
of SR-1222 to  
develop methodology  
for structural  
material selection  
for ship construction.

Conduct a survey of construc-  
tion and operating experience  
of marine concrete structures.  
Develop the basis for a  
research program to provide  
guidance and recommendations  
to designers and builders  
of floating structures. (79-13)

Evaluate recommenda-  
tions for follow-on  
research.

Begin research, e.g., an  
understanding of the  
fatigue requirements and  
performance of large con-  
crete ship structures.

Continue specific  
research as indi-  
cated by previous  
work.

TABLE I

PROJECT AREA	FY 1978	FY 1979	FY 1980	FY 1981	FY 1982
GOAL: IV - MATERIALS CRITERIA (CONT.)					
Materials Trade-Off (Cont.)			Survey of applications, properties of aluminum alloys and weldments, review shipyard fabrication and inspection procedures, and service experience. Identify problem areas. Review SNAME publications.	Follow up programs on data generation, distortion control, weld quality standards, and MDI procedures, as identified in 1979 program.	Design/Fabrication/Inspection Guideline Development
Fracture and Fatigue Control	Explain observed fatigue behavior in terms of measured load spectra developed from ship strain measurements. (SR-1254). Evaluate available procedures for evaluation and selection of fabricated structural details under cyclic-loading conditions. Classify the behavior and severity of ship details under cyclic loading using the best available procedure (SR-1257).	Conduct experimental work to verify the classification procedure selected in the previous work. Conduct experimental work to classify the behavior and severity of details whose behavior is not known. (SR-1257). Monitor the effect of environmental conditions such as sea water and cathodic protection on fatigue crack growth behavior.	Use the results of preceding work and other available information to develop fatigue criteria and design procedure for the selection of ship details under variable amplitude or random loading conditions representative of actual operating conditions for ships. Include both initiation and propagation phases of fatigue.	Review status and applicability of composites. Identify potential growth and problem areas.	Data development programs based upon needs identified in 1981 survey.

TABLE I.

PROJECT AREA	FY 1978	FY 1979	FY 1980	FY 1981	FY 1982
	GOAL: IV - MATERIALS CRITERIA (CONT.)				
	Complete SR-1238.				
Fracture and Fatigue Control (Cont.)	Begin fracture toughness characterization of Ship Steel Weldments (SR-1238).	Complete developing nil ductility temperatures & dynamic tear energies of ship steels. (SR-1224). Deliniate the loading rate effects on fracture initiation. (SR-1231).	Evaluate fracture criteria for ship steels and weldments from information developed in recent SSC projects, SR-1224 and SR-1231. (SR-1265).	Evaluate fracture arrests concepts for ship steels.	Develop an overall fracture-control plan for ship structures that incorporates both fatigue and fracture behavior of fabricated ship details and a reliability analysis.
Corrosion Control	Start a survey and life cycle cost study to identify the most economical corrosion control systems in the existing and projected economic and regulatory climate. (79-10)	Continue monitoring fracture arrest studies of the U.S. Nuclear Regulatory Commission and the Electric Power Research Institute.	Evaluate fracture arrests concepts for ship steels.	Review safety analysis of ship structural details against fracture and fatigue failures. Develop reliability based inspection and maintenance schedules to insure safety against brittle fracture.	Make recommendations for rule and/or design method changes

TABLE I

PROJECT AREA	FY 1978	FY 1979	FY 1980	FY 1981	FY 1982
Improved Weld Quality Guides	<p>Start a survey of existing non-destructive inspection (NDI) methods and adapt them to underwater use. (SR-1243).</p> <p>Begin the survey and evaluation of secondary structural welds such as for webs and longitudinalinals and determine if additional inspection guidelines are needed. (SR-1249).</p> <p>Review NDI practices used for heavy section castings, forgings and weldments. Prepare an interpretive report of the procedures and acceptance limits applicable to ship components. (SR-1255).</p>	<p>Establish the significance of presently-allowed weld defects on the safety and reliability of ship steel weldments using available service stress data, material fracture properties and analysis procedures. Recommend a program to develop improved standards for allowable defect sizes using currently available service experience. (79-8).</p>	<p>Conduct tests as necessary to assist in development of improved standards for allowable defect sizes in ship hull structures. Develop improved methods for obtaining and analyzing permanent records for ultrasonic inspection.</p>	<p>Verify the proposed limits on defect sizes for ship steel weldments by conducting fatigue and fracture tests.</p>	<p>Recommend guidelines for the revised defect size limits in ship construction.</p>

GOAL: V - FABRICATION TECHNIQUES

TABLE I

FY 1982

FY 1981

FY 1980

FY 1979

FY 1978

PROJECT AREA

## GOAL: V - FABRICATION TECHNIQUES

## Welding Design Requirements

Start study to update the allowable shear stress on fillet weld requirements. (SR-1248).

Complete update on allowable shear stress in fillet welds and determine whether research work is needed. (SR-1249).

Undertake such additional fillet weld testing as required.

Provide recommendations for allowable shear stress in fillet welds.

Prepare design guidelines, welding procedures and testing methods to prevent lamellar tearing in ship steels. (SR-1250).

Review SR-1250 Report.

## Effects of High-Deposition Weld Rate

Begin a study to evaluate new improved plate steels for minimum HAZ property degradation, especially with high-heat input processes. (SR-1256).

Complete worldwide literature survey and continue to evaluate weld procedure and metallurgical control for adequate toughness in the HAZ of weldments when using high deposition rate processes. (SR-1256). Consider using test methods developed in SR-1238 to evaluate welding procedures.

Identify critical controls in the development of improved weldments using a variety of high-deposition rate processes and procedures. (SR-1256).

Determine whether new materials and/or processes provide adequate service life using fracture and fatigue tests.

Provide an initial guide for use on high-deposition rate weld processes in ship construction.

Continue to monitor MARAD's program on improved ship steels.

TABLE I

PROJECT AREA	FY 1978	FY 1979	FY 1980	FY 1981	FY 1982
GOAL: VI - DETERMINATION OF SUCCESS/FAILURE CRITERIA (RELIABILITY)					
Buckling/Excessive Deformation/Plastic (Permanent Set)	Develop an analysis method for uncertainties associated with ship hull strength and develop expressions for margins of safety and structural reliability. (SR-1241).	Complete SR-1241.	Formulate risk-related or probability-based criteria for design of ship hulls against specific modes of failure; this may include (a) ships of conventional (steel) material; (b) ships of reinforced and/or prestressed concrete; (c) ships of future marine material, e.g., composites.	Undertake reliability based analysis of past structural failures of ships.	Develop post-damage serviceability evaluations of ship hull structures.
GOAL: VII - DESIGN METHODS					
Design Procedures Efficiency, Economics/Optimization, Test and Evaluation, Preliminary Design.	Evaluate effect of varying ship proportions and hull materials on hull flexibility. (SR-1239).	Review SR-1239 results.			
	Begin SR-1262 to determine the ultimate strength of a ship hull girder.	Develop procedure for determining ultimate strength under combined vertical, lateral, torsional loads. (SR-1262)	Develop procedure for predicting transverse plane motions & transverse & torsional loads.	Fabricate large-scale hull girder model and test to failure, measuring stresses and deformations and comparing with calculations.	Evaluate possibility of using ultimate strength in hull girder design roles.
	Begin supplementary monograph to <i>SHIP STRUCTURAL DESIGN CONCEPTS</i> (SR-1263).	Review existing optimization techniques and develop a computer program for preliminary design. (79-12).	Verify the preliminary design program.		
		Complete SR-1263 monograph.			

TABLE I

PROJECT AREA	FY 1978	FY 1979	FY 1980	FY 1981	FY 1982
Design Procedures (Cont.)					
				Develop preliminary design parameters for ends of ship to avoid vibration and slamming damage.	Study methods and structures to reduce damaging effects of ship collisions using verified computer simulator programs with large-scale ship collision tests.
					Extend design procedure for suddenly applied loads; shock, explosion and thermal shock.

Structural Details	To examine different sound and failed structural details in 50 selected ships (SR-1232). Continue survey on 36 more ships. (SR-1256).	To continue the survey on thirty-six additional ships to establish probability data. SR-1258.	To review and combine previous project results into a design and fabrication manual.
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### Ongoing and Recommended Research

Each project in the current and recommended research program supports one or more of the goals identified in the five-year plan. The principal work represented by these projects is discussed under each goal.

#### Research Plan Development

The SSC has established a two-year project to develop a twenty-year research plan along the lines of a similar undertaking in 1957-1959 and reported in SSC-124, A Long-Range Research Program in Ship Structure Design. A special ad hoc committee is being constituted under the SRC to oversee this effort. The project will include, but not be limited to, two conferences and concurrent work sessions composed of representatives from the operating, fabricating, design, regulatory, classification, military, and research communities. Provision will also be made for public participation.

#### Load Criteria

Consequences of collision and stranding of large oil carriers, LNG ships, and nuclear powered ships and increasing concern for safety and for protection of the environment make this a field of intensifying interest to regulatory agencies and ship designers. Although there are analytical methods for predicting collision damage, they have not been verified by application to actual cases. Data on impact velocities, attitudes and relative positions of striking and struck vessels at impact and quantitative

description of resulting damage are lacking. Efforts to obtain this information from available reports of collisions have proven fruitless. Procedures for obtaining necessary data will have to be established and cooperation of the parties involved assured to permit its collection. Future projects will address this problem using scale models and possibly full-scale tests to provide data for verification of mathematical models. Two projects continue active in this program, one to identify and monitor research on collisions and strandings, the other to critically evaluate and refine collision damage theories.

The probability of increased shipping activities in polar regions and indications that the selection of degrees of ice strengthening are not always adequate to the conditions experienced have prompted the recommendation of a project to survey the ice-strengthening of vessels encountering ice conditions in various parts of the world.

A project is recommended to provide data on the variation of bending loads resulting from operating cycle cargo variations, thermal loads from ambient and cargo temperatures and other quasi-static conditions. These loads are significant components of the total bending load spectrum for a ship, and little actual data exist regarding magnitudes and variation with time.

The phenomenon of sloshing of liquids in large cargo tanks can result in large loads on the boundary structures. The wave action within these tanks is highly

nonlinear and there is no validated method for design. A project is in progress to develop such a method for LNG tanks and verify it by scale-model tests. The extension of this work to other liquid cargoes recommended in the FY 1977 program has been deferred as recommended by the SSC until the results of the present LNG work are evaluated.

Further exploration of vibration problems, beyond a project now under way to develop a rational approach to the analysis of propeller-induced vibration, has been deferred until after the SSC-SNAME sponsored Vibration Symposium to be held in Arlington, Va., October 16-17, 1978.

The SSC has asked the SRC to recommend an approach to the coordination of ocean wave data gathering efforts. These are currently done by a variety of organizations around the world, for a variety of purposes and with a concomitant variation in what is recorded and how. This will be the subject of a review by the SRC and people knowledgeable in the field and an appropriately documented response to the SSC. Studies by the Marine Board and the Space Science Board of the National Academy of Sciences that bear on this problem will provide useful input to this review.

The lack of a reliable wave measuring device, a problem that has plagued full-scale investigations of ship response in waves, remains. Developments in this field, notably a USCG project to evaluate radar altimeter devices,

such as the one employed in the SL-7 program and the full-scale slamming project, are being monitored.

#### Response Criteria

The SL-7 model/analytical/prototype research program, begun in 1972, is recommended to be extended by the recording of two more years of scratch gage data. This will extend by 16 ship years the long-term statistics on extreme stresses. Meanwhile, the value of this and further data collection on the SL-7 class of ships will be evaluated and the possibility of transferring the gages to other ship types examined. Reduction of accumulated data, evaluation and comparison of results continues in three active projects. A recommended project to verify, by means of model tests, the hydrodynamic pressures and their distribution predicted by potential theory for a ship moving through waves will also employ the SL-7 model as one of its subjects. Once established, the theory will provide realistic pressure distribution input to ship structure analysis programs that is now lacking.

Distortion limits imposed by the requirements of main propulsion machinery components bear little relationship to the deflection of hull structure in the way of prime movers, gears, bearings and shafting. A study is recommended to determine current practices and design, specified tolerances or limits as exemplified by representative large modern ships. Available analytical methods will also be examined and, if possible, guides and

numerical values for hull and support stiffness parameters will be proposed.

#### Materials Criteria

A materials trade-off study is developing a methodology for the direct synthesis of material property requirements in the design process. Aluminum is the candidate substitute for steel in bulk carriers. It is anticipated that reinforced concrete and composites will eventually be included in the program. To this end, a state-of-the-art study of reinforced concrete, including prestressed and poststressed concrete in ship construction, has been recommended.

Since safety and reliability of ships are of paramount importance, projects to identify control parameters governing fatigue cracking, fracture initiation and propagation are under way. Data on measured ship load spectra are being gathered and will be correlated with developed fatigue data of various ship structural details. The effect of environmental conditions on fatigue crack growth and corrosion control will be evaluated. Soon to be prepared is an interpretive report on the correlation of fracture toughness in ship steels and weldments with proposed criteria for adequate fracture resistance in service. This document is to contain an in-depth analysis of the brittle fracture characteristics of ship steels and weldments data developed by the SSC and from pertinent data in the literature or company files that may also exist. The

intent is to determine whether sufficient data are available to adequately assess the fracture criteria; if the fracture test methods being proposed are adequate measures of material performance in ship application; and if modifications to the proposed criteria are needed.

#### Fabrication Techniques

To reduce construction costs of welded ships, high-deposition rate welding processes are coming into use. A project is being started to examine properties and microstructures in the heat affected zone (HAZ) of welds in relationship to welding conditions in order to determine those welding procedures and base metal parameters that result in degraded HAZ properties. Other welding programs, such as the MARAD-sponsored study on improved ship steels, are being followed in order to avoid duplication of effort. It is possible that some of the improved steels in that program may prove more adaptable to high-heat inputs than the currently available ship steels in the SSC program.

Since 1961, the fillet weld allowable shear stress has been 13,600 psi for E60 weld metal and 15,800 psi for E70 weld metal. These requirements are now being reviewed in light of recent test data to determine if the allowable stresses can be increased. If so, a substantial savings will occur because 75% of the weld footage in ship hull construction is fillet welded.

Lamellar tearing of welded structural steels-- separation in the parent or base metal of a heavy plate,

usually just outside of the HAZ in a welded joint--is a continuing concern of the ship-building industry. New techniques for assessing materials and new methods for prevention of cracking have provided the opportunity to develop reasonable design guidelines, welding procedures, and testing methods to prevent lamellar tearing in ship structures. The SSC is preparing a guide that will inform designers and welding engineers how to avoid situations that invite lamellar tearing and how to assess a detail's tearing susceptibility.

The important area of nondestructive inspection (NDI) of weldments is addressed in a recommended project to assess weld quality based on fracture mechanics analysis and consideration of existing fracture and fatigue test data obtained for weld joints with defects. Other NDI studies still in progress cover state-of-the-art studies on the underwater NDI of welds, radiography guidelines for secondary members, and the NDI of heavy section castings, forgings, and weldments.

#### Determination of Success/Failure Criteria

To meet this goal, the SSC has undertaken a project to develop a methodology to analyze the uncertainties associated with ship hull strength that are not presently considered in the design process. Some complementary work toward this goal is also being done in determining the mechanisms of potential failure of the hull girder. Depending upon the loading conditions, one mechanism may be

more serious or dominant than another: for example, certain failure modes may be important in sea-keeping, but the same modes may not be dominant in collision or stranding. Recommendations for the future effort will include work to better understand the effects of scale and geometry especially as they relate to buckling, fatigue and fracture.

#### Design Methods

Trends in the proportions of large bulk carriers are leading to extreme values of length to depth and length to beam ratios. These go beyond experience, and the answer to how far these trends can safely go is not known. A study is under way that attempts to assess by advanced analytical methods the influences of hull proportions on deflections and stresses in a seaway.

A project for the analysis of the ultimate strength of ship's hull girder will contribute a necessary element in the definition of true margins of safety, which are currently not realistically estimated.

Extension of the structural detail failure survey to 36 additional ships to expand the statistical data base is under way.

A project titled "Computer-Aided Preliminary Ship Structural Design" is also recommended. It is aimed at assessing the possibilities of technology transfer, from the aerospace and civil engineering communities, of structural design optimization methods that may be applicable to the design of ship structures.

### FISCAL 1979 PROJECT RECOMMENDATIONS

Table II lists the projects proposed for the 1979 Fiscal Year in priority order. Prospectuses for these projects are presented in the same order. Some of the prospectuses may seem specific and detailed, whereas others appear to be general. This is purposely so, reflecting the judgment of the SRC that potential contractors should be constrained on certain projects and encouraged to propose their own approaches or methods for others.

As in past years, more projects are included than are likely to be funded with the anticipated support. However, the possibility of greater support, the need of the SSC for a reasonable number of projects from which to select, and the possibility that some projects not initiated in Fiscal Year 1979 could well be included in the program for the following year, suggest that the preparation of the additional prospectuses is a useful service.

TABLE II - RECOMMENDED PROJECTS FOR THE 1979 FISCAL WORK

<u>PRIORITY</u>	<u>PROJECT TITLE</u>	<u>PAGE</u>
1	Investigation of Steels for Improved Weldability in Ship Construction (SR-1256)	33
2	Fatigue Characterization of Fabricated Ship Details (SR-1257)	35
3	Criteria for Hull Machinery Rigidity Compatibility	37
4	Evaluation of SL-7 Scratch-Gage Data	39
5	A Long-Range Research Program in Ship Structures (SR-1259)	41
6	Ice Strengthening Criteria for Ships	43
7	SL-7 Extreme Stress Data Collection (SR-1215)	45
8	Weld Quality Levels Required for Ship Structural Integrity	46
9	Computer-Aided Procedure for Drydocking and Ship Grounding Calculations	49
10	Internal Corrosion and Corrosion Control Alternatives	52
11	Pressure Distribution Model Tests in Waves	56
12	Computer-Aided, Preliminary Ship Structural Design	58
13	Survey of Experience Using Reinforced Concrete in Floating Marine Structures	59
14	Static and Quasi-static, and Thermal Loadings	61

SR-1256, "INVESTIGATION OF STEELS FOR  
IMPROVED WELDABILITY IN SHIP CONSTRUCTION"

SRC Priority 1

Long-Range Goal: Materials Criteria, Fabrication

#### BACKGROUND

Domestically, experimental work on electroslog and electrogas welding for marine applications has identified the need for an improved ship hull steel that would have minimal tendencies for degradation of the heat-affected-zone (HAZ) and weld-metal properties. Related work is directed toward preserving HAZ toughness in steels for service temperatures to approximately -50°C. Weldments that use higher deposition rate welding practices in low-sulfur and sulfide-shape-controlled plate steels are being evaluated. Additional metallurgical control appears necessary for minimizing degradation of HAZ and weld-metal properties. A project along these lines was approved by the Ship Structure Committee at its June 2, 1977 meeting. Since only one year of work was authorized at that time, additional funding and authorization are required to continue the work through the second year.

#### WORK SCOPE

The contractor will conduct a literature survey to determine the state of the welding art in shipbuilding and related industries. New processes, plate materials, and the structural areas in which they are used will be identified. Current U.S. and foreign techniques will be compared. A

cost analysis of the use of improved steels or welding techniques will also be made.

Exploratory tests will be conducted to supplement the information in the literature survey.

The most promising tests will be used to evaluate several ABS grades of hull structural steel and the metallurgical factors for improved Heat-Affected Zone (HAZ) performance will be identified.

Finally, welding tests will be conducted to determine the effects of compositional and heat treatment modifications to ship steels.

MAN-HOURS

First Year	-	2000 (approved June 2, 1977)
Second Year	-	3000
Third Year	-	3000

SR-1257, "FATIGUE CHARACTERIZATION OF  
FABRICATED SHIP DETAILS"

SRC Priority 2

Long-Range Goal: Fabrication, Load Criteria

BACKGROUND

Ships under actual operating conditions are subjected to cyclic loadings that start and propagate fatigue cracks in details at critical locations. There is a need to evaluate the behavior and useful life of fabricated ship details under cyclic-loading conditions.

The result should be a classification of fabricated ship details in terms of their behavior and useful life under cyclic-loading conditions, using the best available design and selection procedure to ensure the safety and reliability of ship details. The research should also result in specific recommendations for implementing the findings in the design of ships.

In June, 1977, the Ship Structure Committee approved starting such a project intended to have a two-year duration. In order to continue the work through the second year additional funding and authorization are required.

WORK SCOPE

The following work is to be accomplished in the first year:

- a) Appraise available procedures for evaluating and selecting fabricated structural details under cyclic-loading conditions,

b) Classify the fatigue behavior and determine the useful life of ship details under cyclic loading, using the best available procedure.

The tasks for the second year are:

a) To verify the classification procedure selected in the previous work,

b) To classify, according to the selected procedure, the behavior and useful life of fabricated ship details whose behavior is not known.

MAN-HOURS

First Year	-	2000 (Approved June 2, 1977)
Second Year	-	3000

CRITERIA FOR HULL AND MACHINERY  
RIGIDITY COMPATABILITY

SRC Priority 3

Long-Range Goal: Response Criteria

BACKGROUND

Recent trends to high horsepower in ships give urgency to problems of compatibility between local hull deflections and distortion limits imposed by the requirements of the main propulsion machinery components. Some work has already been undertaken in the field of the deflection of cross-stiffened panels notably SSC-270, "Gross Panel Strength Under Combined Loading." Additional work is underway in Project SR-1239, "Rational Limit of Hull Flexibility." There needs to be a study made of the distortion limits imposed by the machinery manufacturers because of bearing loading, misalignment, gear teeth wear, and excessive vibration. The relationship between these requirements and the flexibility of the machinery foundations and the ship's structure needs to be evaluated.

WORK SCOPE

Develop criteria for hull and machinery rigidity compatibility.

SPECIFICATIONS AND SPECIAL PROVISIONS

The contractor shall:

1. Survey major U.S. and foreign machinery manufacturers to determine their requirements for rigidity of the main engine supports. Standards should be sought for slope change of shaft as well as for deflection.

2. Review the design of main engine, gear, and thrust bearing support structures of several large modern ships with regard to:

a. Overall arrangement and scantlings of main support members such as deep transverse webs, longitudinal girders, transverse and longitudinal bulkheads, and horizontal flats.

b. Arrangement and scantlings of structure in way of main reduction gears.

c. Arrangement and scantlings of shaft bearing and thrust bearing supports and stiffness of shaft.

d. Tolerance of gear train to withstand the environment.

3. Review available analytic procedures for determining the coupled response of hull and machinery.

4. On the basis of the results of this survey, identify a set of standards that will define the structural rigidity of machinery support systems and determine values that will represent current successful design practice. If possible, the values for any designs known to have given difficulties with gear wear, bearing wear, vibrations or misalignment should be identified.

MAN-HOURS

1000

## EVALUATION OF SL-7 SCRATCH-GAGE DATA

SRC Priority 4

Long-Range Goal: Load Criteria, Verification

BACKGROUND

Previous SSC projects directed toward establishing load criteria on a probabalistic basis showed lifetime extreme loads could not be predicted with confidence. To develop the confidence required, mechanical scratch gages were installed on eight SL-7 ships: the SEA-LAND McLEAN, GALLOWAY, COMMERCE, EXCHANGE, TRADE, FINANCE, MARKET and RESOURCE. The contractor has obtained data tapes, either by mail or by visiting the ships for maintenance of the gages. The tapes have been annotated and mounted in folders and forwarded to the Ship Structure Committee.

These data must now be examined in some detail to relate them to the results of the SL-7 electrical strain gage data collection program and to determine if additional collection time is needed to develop the necessary confidence for prediction of extreme loads. A total of 20 ship-years experience will be obtained in these first five years, since the ships were instrumented only as they were delivered to the owners.

WORK SCOPE

The contractor shall evaluate SL-7 scratch gage data as a basis for extreme load prediction, to determine correlations with SL-7 strain gage data, and to recommend when and how many scratch gages can be recovered for placement aboard other ships.

SPECIFICATIONS AND SPECIAL PROVISIONS

The project will require accomplishing the following task:

1. Correlate the McLEAN scratch gage data developed under project SR-1245, "Reduction of SL-7 Scratch Gage Data," and the recorded strain gages data from the various pertinent strain gage transducers obtained under project SR-1211, "SL-7 Data Collection Program."
2. Process the data available through June 1978.
3. Establish a measure for judging when sufficient data have been obtained so that scratch gages can be transferred to other ships. Considerations should be given to the effects of corrosion that will tend to raise the observed strains.
4. Write a report describing the methods used in the study and present the results in a form for use by a naval architect.

MAN-HOURS

1200

SR-1259, "A LONG-RANGE RESEARCH  
PROGRAM IN SHIP STRUCTURES"

SRC Priority 5

Long-Range Goal: All of them

BACKGROUND

The Ship Structure Committee approved a project at its June 2, 1977 meeting to develop a long-range, twenty-year plan to guide ship structural research and development programs to solve the needs of the maritime community. This plan will encompass not only the technical factors, but also those environmental, economic, political, and military factors that might be expected to influence both the course and the development of a technical program. Since only one year of work was authorized at that time, additional funding and authorization is required to continue the work through the second year.

WORK SCOPE

The contractor shall develop a planning document directed toward, but not be limited to, the technical goals and charter of the SSC, and shall forecast the research and development needs, based on a priority system, for the next twenty years. Areas of interest shall include commercial and military surface ships of conventional and advanced design, fixed and floating marine platforms, ocean and inland service, as well as possible special service requirements, such as arctic operations, as may be required for commercial or military needs. Major emphasis will be placed on conventional and advanced surface ships. The

final planning document shall include background material, proposed technical approaches, technical man-hour estimates, benefits of each project, and multiple benefit listing to the Ship Structure Committee. The report shall also include the methodology used in identifying each of the benefits so that, in the future, options can be reassessed in light of the current situation.

MAN-HOURS

First Year	-	4000 (Approved June 2, 1977)
Second Year	-	4000

## ICE STRENGTHENING CRITERIA FOR SHIPS

SRC Priority 6

Long-Range Goal: Design Methods, Advanced Concepts

BACKGROUND

In coming years, shipping will increase in arctic areas. Consideration must be given to strengthening existing hulls in certain locations, and selection of materials having proper toughness values at low operating temperatures. Welding materials and processes, and fabrication methods must also be selected to meet the arctic operating temperatures.

Section 29.1 of the 1977 ABS rules states that the ship owner will select the class of ice strengthening for a vessel destined to operate in ice-infested waters. Selection is based only upon the judgment and experience of the owner. The ice damage to the USNS MAUMEE, and to other Class "C" ice-strengthened MSC ships such as the TOWLE and WYANDOT suggest that these criteria have not always been adequate. Yet, little guidance is available for determining what class the ice strengthening should be (ABS Class AA, A, B, C, IAA, IA, IB or IC).

WORK SCOPE

The contractor shall: (1) review pertinent U.S. and foreign literature and list significant references, (2) identify ice strengthening criteria and related data, (3) review the characteristics and classes of a variety of ice strengthened ships, their normal areas of operation, and their ice-damage histories, (4) review the ice histories of

the Arctic and Antarctic oceans and surroundings, the St. Lawrence Seaway, and other ice-prone navigable waterways to identify ice characteristics that have occurred using the codes of the World Meteorological Organization and to establish measures of mean and maximum ice accretions.

#### SPECIFICATIONS AND SPECIAL PROVISIONS

1. The final document shall categorize ice data for the oceans, the principal navigable lakes, rivers, and seas, and identify the class of ice strengthening for vessels plying them.

2. A tabular comparison of ABS and other classification societies' rules for ice strengthening shall be prepared.

3. The report will include a survey of materials and fabrication techniques for ice strengthening.

4. The document shall address the economics of the various classes of ice strengthening for different sizes of vessels. A percentage comparison of costs is suggested, e.g., that Class "AA" costs X% more than Class "B", etc.

5. U.S. Coast Guard records of past ice damage utilizing Damage Survey Analyses will be reviewed.

6. The report will recommend needed research for rational selection of ice strengthening measures for ships.

#### MAN-HOURS

2000

SR-1215, "SL-7 EXTREME STRESS DATA  
COLLECTION"

SRC Priority 7

Long-Range Goal: Verification, Load Criteria

#### BACKGROUND

The SL-7 Program has provided a unique opportunity to collect extreme stress data on eight sister ships. Scratch gages were installed on all of the ships by December 1973, from which data tapes have been collected regularly and the equipment maintained in good order. At the beginning of the project, it was anticipated that approximately 40 ship-years of data would be available after five years. The data for the first four years have been processed and the cumulative long-term distribution has been examined, but not yet related to other elements of the SL-7 Program. It is recommended that, in the interim, the collection of data be continued.

#### WORK SCOPE

The contractor will continue to service the gages on the eight ships for an additional two-year period and will collect and transmit to the Ship Structure Committee the completed tapes according to the current procedures.

#### MAN-HOURS

600 hrs/yr

**WELD QUALITY LEVELS FOR SHIP STRUCTURAL  
INTEGRITY**

SRC Priority 8

Long-Range Goal: Fabrication

**BACKGROUND**

Weld quality standards are generally established on the basis of workmanship considerations. The acceptance limits are set such that a qualified welder using the appropriate procedures and equipment can consistently meet the quality standards. Service experience demonstrates that these standards result in welds of good long-term structural integrity. However, in many cases these quality standards bear no relationship to defect size limits needed to assure structural integrity. If defect tolerances could be relaxed without adversely affecting the strength and durability of the ship, considerable cost savings could result through the use of more efficient procedures and by eliminating unnecessary repairs.

Over the past decade, considerable progress has been made in technologies used to establish rational weld quality standards: e.g., fracture mechanics, nondestructive inspection (NDI), and loads and stress analysis. The Ship Structure Committee has contributed to this knowledge through studies of fatigue and fracture behavior of ship steels, ship loads, response and stress analysis and NDI of ship steel weldments. This extensive body of knowledge needs to be applied to a reconsideration of allowable defect sizes in welds.

#### WORK SCOPE

The contractor shall develop weld quality measures based on fracture mechanics analysis and consideration of existing fracture and fatigue test data obtained for weld joints with defects. A comparison of these measures with current requirements will be used as the basis for recommendations.

#### SPECIFICATIONS AND SPECIAL PROVISIONS

The contractor shall:

1. Summarize the existing weld quality standards in terms of allowable size for each type of defect.
2. Conduct a fracture mechanics analysis using a fatigue stress spectrum and maximum credible stresses based on SL-7 and other ship loads data banks, fatigue crack growth data from report SSC-251, A Study of Subcritical Crack Growth in Ship Steels, and fracture toughness data from projects SR-1224, "Fracture Criteria" and SR-1231, "Fracture Criteria Based on Loading Rates."
3. Review available information on the influence of weld defects on fatigue and fracture behavior of ship steel weldments, including weld metal and parent steel.
4. Develop an alternative set of weld quality standards based on the information of steps 1, 2 and 3.
5. Summarize data needed for greater assurance that the alternative weld quality standards are valid.
6. Compare the alternative standards with current requirements.

7. Recommend future work that will lead to improved weld quality standards.

MAN-HOURS

2000

## COMPUTER-AIDED PROCEDURE FOR DRY DOCKING AND SRC Priority 9 SHIP GROUNDING CALCULATIONS

Long-Range Goal: Design Methods

### BACKGROUND

A quick method for calculating the stresses on a ship when dry docking is needed. Transfer of the ship weight from hydrostatic support to ground support requires reordering strains throughout the ship's structure. It also produces heavy local loads on the keel blocks, which will affect the structure of floating docks and the ground support system of graving docks. It is possible to consider the stranding condition of a ship as a special type of dry docking.

Current analysis methods require laborious, time-consuming hand calculations by an experienced analyst in this field. A computerized system would greatly reduce the analysis time and improve the ability to evaluate dry-docking problems (including those for damaged ships).

### WORK SCOPE

The investigator shall develop a computer program and prepare a programmer's and a user's manual for dry-docking and ship stranding analysis.

### SPECIFICATIONS AND SPECIAL PROVISIONS

1. The investigator shall analyze the factors that affect the ship and the dock stresses during the transfer of ship support.

2. The investigator shall develop a program that will accept ship's Bon Jean curves, the ship's longitudinal weight distribution curve, the ship's stability, and the ship's deviations from designed form characteristics. In the case of dry docking, the program will take the dock's buoyancy, weight, stability and strength characteristics into consideration. In the case of grounding, the support system should incorporate variable spring constants over varying length of the ship's bottom or other measures of a varying support system.

3. The input data should be organized to be compatible, insofar as possible, with the current version of the Navy's Ship Hull Characteristic Program.

4. The program should be organized to accept three packages of data:

- i) ship's characteristics (actual or designed)
- ii) dock's characteristics
- iii) sea-bottom support properties

5. The program should produce the following information:

- a) drafts forward, aft, and midship of ship and floating dock
- b) a quantitative evaluation of the loads and stresses in both ship and floating dock

- c) a quantitative evaluation of stability of both ship and floating dock.

6. The final report shall include documentation of program development.

MAN-HOURS

2000

INTERNAL CORROSION AND  
CORROSION CONTROL ALTERNATIVES

SRC Priority 10

Long-Range Goal: Materials Criteria, Fabrication,  
Design Methods

BACKGROUND

As a result of trends in tankship and bulk carrier design over the past decade, scantlings have been reduced significantly, saving steel, weight, and construction cost. Minimum scantlings required by classification societies have been reduced owing to better understanding of actual service loads and improved methods of stress analysis. Application of sophisticated long life (5 to 10 year) coating systems, alone or in conjunction with sacrificial anodes, in ballast tanks and ballasted cargo tanks permits a further reduction in scantlings, i.e., full or partial elimination of the "corrosion margin".

Several recent developments suggest that re-examination of this philosophy may be timely, both for existing and new tankers and bulk carriers.

- (a) Ship construction and repair costs have quadrupled in the past ten years. Steel repairs, renewals, or re-application of coatings or anodes in some areas of larger ships are nearly impossible or prohibitively expensive. As to existing ships, these factors indicate a need to look for less expensive ways of extending the lives of ship

structures; this probably means less sophisticated coating systems. For new construction, these factors cause owners to look at the marginal cost of "extra" steel thickness as a more economical approach, on a life-cycle basis.

- (b) Recent proposed regulations (USCG's May 16, 1977 proposals) would require all tankers over 20,000 Dwt to provide ballast volume in segregated ballast tanks of 30 to 40% of their deadweight. In new ships, this ballast must be distributed close to the shell and bottom in narrow tanks with limited access. Space and access restrictions would increase the cost of coating application and probably preclude use of coal tar epoxy, one of the most effective. Tank geometry would also increase scouring and other effects from sediment. However, coating failure in tanks with reduced scantlings would be disastrous, as some recent cases have demonstrated.

#### WORK SCOPE

The investigator shall assemble representative cost data on new construction and repair, fabrication, and coating for U.S. and foreign tankers. From market data on cargo revenues and from existing data on corrosion rates and coating lives, he shall develop a method for making

sensitivity studies of the relative life-cycle costs of available corrosion control techniques, including combinations of increased scantlings, full or partial coatings, and anodes. Using this method, the investigator will work several examples for a range of ship sizes and make recommendations about the relative emphasis that could be placed on further investigation of corrosion control philosophies.

#### SPECIFICATIONS AND SPECIAL CONSIDERATIONS

1. In conducting the survey, the investigator should limit the study to protection of internal surfaces of ballast and cargo tanks in steel tankers.
2. Tasks shall include, but not necessarily be limited to, the following:
  - a) Collect, for different areas of the structure, construction and repair costs for steel, coating, and anode work, in U.S. and foreign yards, from published sources, owners, and yards.
  - b) Collect existing published data, including that implied by classification society rules, of corrosion rates in cargo and ballast tanks with various protection systems.
  - c) Develop a method, or calculation procedure, for taking into account life-cycle costs of various corrosion control systems.

- d) Evaluate the relative effectiveness of various corrosion control systems based on published data and data solicited from classification societies and owners.
- e) Perform sensitivity calculations of life-cycle costs of various corrosion control systems for segregated ballast tankers as follows:

30,000 Dwt Clean Petroleum Product Tanker

250,000 Dwt Crude Carrier

3. The report shall summarize and tabulate survey findings and indicate those systems that appear most worthy of additional study based on the sensitivity analyses.

4. No experimental or ship instrumentation work is to be undertaken.

MAN-HOURS

2000

**PRESSURE DISTRIBUTION MODEL TESTS IN WAVES SRC Priority 11****Long-Range Goal: Load Criteria, Design Methods, Verification****BACKGROUND**

Current SSC programs deal primarily with sea loads imposed on the hull girder. In addition, knowledge of pressures on the hull surface is also needed to determine the required strength of local structures to withstand maximum anticipated pressures at sea. Since computer programs for calculating pressure distributions are available to the profession, it is worthwhile to verify the results of computation by model experiment.

There are several reasons for preferring model, rather than full-scale tests for evaluating the computer program. The most obvious reason is the prohibitive cost of instrumenting a ship for a pressure distribution study. Sea conditions can be simulated in the wave tank, model motions can be accurately measured, and pressure distributions can be simultaneously recorded by means of a computerized system.

**WORK SCOPE**

The contractor shall undertake towing tank model tests of the SL-7 containership and an appropriate full-form vessel to measure pressures on the hull surface for determining the required strength of local structures to withstand the maximum anticipated pressures at sea and to compare these measured pressures with pressures calculated using the potential theory.

SPECIFICATIONS AND SPECIAL PROVISIONS

The contractor shall:

1. Obtain (or build) a model of the SL-7 containership and an appropriate full form vessel.
2. Insert a number of pressure taps at each of a sufficient number of stations on one side of each model's hull to obtain the necessary data simultaneously from various subsets of the taps so that the pressure data from each tap can be graphed against time.
3. Conduct towing tank model tests in regular waves of various wave lengths and at 2 or 3 speeds.
4. Measure the response of the models at each wave length.
5. Use a computerized system to produce time history data from the pressure transducers.
6. Obtain calculated pressures from the American Bureau of Shipping that they will furnish free, produced under the same conditions of model dynamic characteristics and wave conditions.
7. Evaluate and compare model and calculated results.
8. Indicate those areas where the computer program or the model test technique should be improved.
9. Develop, but do not undertake, a similar program for the models in oblique sea headings.

MAN-HOURS

2400

**COMPUTER-AIDED OPTIMAL PRELIMINARY  
SHIP STRUCTURAL DESIGN**

SRC Priority 12

Long-Range Goal: Design Methods

**Background**

Computer-aided design of bridges and aircraft structures has reduced construction costs and improved structures. An assessment should be made of the potential improvement to ship design by transferring this technology. The assessment must be made by experienced ship designers.

**WORK SCOPE**

The goals can be accomplished by reviewing applications of computer-aided design in both ship and non-ship areas of preliminary structural design. The potential benefits of computer-aided ship structural design should be assessed and possible courses of action reviewed.

**SPECIFICATIONS AND SPECIAL PROVISIONS**

The contractor shall:

1. Survey the state-of-the-art of computer-aided preliminary structural design in ship design and other disciplines.
2. Review available computer-aided design systems. In particular, survey the capabilities of the NASA IPAD system.
3. Assess the potential benefits of increased use of computers for system optimization in preliminary ship structural design.
4. Develop an in-depth plan for future action.

**MAN-HOURS**

1000

SURVEY OF EXPERIENCE USING REINFORCED  
CONCRETE IN FLOATING MARINE STRUCTURES

SRC Priority 13

Long Range Goal: Materials criteria, Design methods,  
Fabrication

BACKGROUND

Reinforced concrete, including prestressed and poststressed concrete, has been suggested as a building material for large ocean-going ships, as well as for moored, floating process and storage plants. Some of these proposed applications envision concrete structure in direct contact with cryogenic gas liquids at temperatures down to  $-260^{\circ}\text{F}$ . In all cases, concrete is in contact with sea water during the operating life of the hull. The proposed structures are generally of ship or barge shape, ranging in size up to 1,000' long and 300' beams. Process machinery plants up to 200,000 hp may be installed. Strength, safety, and maintenance should be equivalent to a comparable steel structure through the life cycle. Materials data and design criteria are needed for reinforced concrete in such applications. The ultimate goal in this overall subject area (though not of this project) is to provide guidance and recommendations to those who design, build, and operate such structures.

WORK SCOPE

The contractor shall review and report on service experience, materials data, design criteria, fabrication procedures, and inspection techniques, both domestic and foreign, for reinforced concrete including prestressed and

poststressed concrete, applicable to floating marine structures. Identify information shortages or gaps and make recommendations for follow-on research.

#### SPECIFICATIONS AND SPECIAL PROVISIONS

1. The contractor should become familiar with the various concepts for the use of reinforced concrete in large floating structures. Recent experience with large marine bottom-sitting (stationary) tank structures and platforms should be included, where applicable.

2. The state-of-the-art report should be aimed at identifying applicable work and where future research and development emphasis may be needed.

3. The contractor should be alert for and report potential applications of reinforced concrete not presently being pursued.

4. The contractor's work product is to be prepared from previously reported work, interviews, inspections, etc.; no experimental work is desired.

#### MAN-HOURS

1000

STATIC AND QUASI-STATIC, AND THERMAL  
LOADINGS

SRC Priority 14

Long-Range Goal: Load Criteria, Verification, and Design  
Methods

BACKGROUND

SSC-240, Load Criteria for Ship Structural Design,  
discusses the establishing of:

- A. The still-water bending moment (SWBM)
- B. The ship's speed-induced wave-bending moment  
(SIWBM)
- C. Thermal effects

As to the SWBM, the difficulty of obtaining  
complete cargo and liquid weight distribution is apparent.

For any loading, approximate and exact methods of  
calculating the SWBM are treated in SSC-240, and mention is  
made of commercially available instruments permanently  
installed in a vessel to measure stresses and bending  
moments at any time.

Currently, it may be presumed that any designer or  
builder of large vessels would make SWBM calculations, for  
classification societies relate deck section modulus to  
SWBM, and it is standard practice today to provide loading  
manuals for the guidance of ship operating personnel.

In SSC-240, the investigators conclude that what is  
required for any ship is an estimate of the means and  
standard deviations of outbound and inbound bending moments  
over many voyages, with probability density curves (in lieu  
of cumulative distribution) showing the probability of

different SWBM levels for use in estimating the SWBM for both outbound and inbound loadings (perhaps only one loading for true container ships). The subject of probability level is treated in Chapter VIII of SSC-240

Speed-induced wave-bending moment will vary with draft, trim, and speed. A wave profile can be established from model tests, measured full scale, or estimated from photographs of a vessel at known speed, all in calm water. Estimates of the wave profile, change in trim, etc., from model series tests, are limited to the fullnesses pursued in the series. For example, Series 60 embraces block coefficients from .60 to .80. Unique forebody configurations, including bulbs, large-radius stems, unusual Length to Beam (L/B) ratios, etc., especially influence the wave profile. For many types of vessels, a singular pursuit of the wave configuration and trim change would probably be required.

It is significant that few loading manuals reflect the ship-induced wave-bending moment.

As to thermal effect, the discussion in SSC-240 is limited to the sea and ambient air temperatures, and the influence of the sun, omitting direct or indirect heating or cooling of hull girder members from relatively hot or cold products carried by the vessel.

Asphalt in the liquid state has been carried in center tanks of vessels arranged as typical tank vessels (except for an inner bottom under the asphalt), causing

severe temperature variations among major hull girder elements.

Molten sulphur, even when carried in tanks independent of the hull, considerably raises the temperature of adjacent hull structure.

Cryogenic cargo tanks have generally been better insulated than heated cargo tanks, particularly where no attempt is made to refrigerate the cargo. . SSC-241, Thermoelastic Model Studies of Cryogenic Tanker Structures, discusses only sudden flooding of LNG into a hold surrounding the insulated tank, and does not directly relate to the general hull bending moment via thermal influence.

SSC-240 suggests that the thermal influence objective is to obtain clear statistical or probabilistic pictures of thermal conditions which cause a diurnal change in stress level. . Such stresses obviously must be algebraically additive to constant thermal stresses from cargo heat or cold.

#### OBJECTIVE

To obtain usable SWBM data, SIWBM data, and thermally induced bending moment data for typical ship types on a probabilistic basis where pertinent.

#### DESCRIPTION OF WORK

1. Determine ship types needed for study, including speeds and fullnesses for each, divided where necessary into sub-categories (as for example, broad range of L/B for tankers).

2. Determine accuracy and sensitivity of commercially available loading instruments ("Lodicator", "Loadmaster", etc.).

3. If encouraging results arise from task 2, create a program and produce probabilistic data for each ship type and sub-type, thus providing SWBM and SIWBM levels for outbound and inbound loadings as pertinent, based on actual operating data.

4. If commercial loading instruments prove unreliable, create a program and produce the information asked for in 3, using light ship weight data, designers, builders, and classification societies' calculations, and actual operating data for the SWBM; and model basin or other source data for the SIWBM for the speeds, drafts, and trims found in actual operation.

5. Establish the bending-moment influence on the hull girder for pertinent types of ships, from hot or cold products carried, reflecting current practice for the trades involved.

6. Establish the diurnal thermal stress levels for the vessel types and sub-types, on a probability basis.

MAN-HOURS

2600

### REVIEW OF ACTIVE AND PENDING PROJECTS

This section of the report covers current projects funded with fiscal 1977 (or earlier) funds, others that have been started with fiscal 1978 funds, and several projects for which proposals are not yet in hand but are anticipated to be supported with fiscal 1978 funds. These projects, listed in Table III, constitute the current program.

Project descriptions, including the SP project number and title, the names of the principal investigator and his organization, where these have been determined, and the activation date and funding, where applicable, are provided. The appropriate SSC Long-Range Goal is also noted, and a very brief statement of the objective of each project is given. These are followed by a short description of the present status of the project.

This format does not permit a detailed or comprehensive description of individual projects; however, each project included will normally result in one or more SSC reports.

TABLE III -- REVIEW OF ACTIVE AND PENDING PROJECTS

<u>SR-NO.</u>	<u>PROJECT TITLE</u>	<u>PAGE</u>
SR-1215,	"SL-7 Extreme Stress Data Collection"	68
SR-1222,	"Materials Trade-Off Study"	69
SR-1227,	"Load Criteria Application"	70
SR-1236,	"SL-7 Stress Calculations Compared with Full-Scale Measured Values"	71
SR-1237,	"Critical Evaluation of Low-Energy Collision Damage Theories and Design Methodologies"	72
SR-1238,	"Fracture Toughness Characterization of Ship Steel Weldments"	73
SR-1239,	"Rational Limit of Hull Flexibility"	74
SR-1240,	"Propeller-Induced Vibration in Hull Structural Elements"	75
SR-1241,	"Longitudinal Strength Criteria Based on Statistical Data Analysis"	76
SR-1243,	"Underwater Nondestructive Inspection of Welds"	77
SR-1245,	"Reduction of SL-7 Scratch-Gage Data"	78
SR-1246,	"Surveillance of Ship Collision/Stranding Research Studies"	79
SR-1248,	"Updating of Fillet Weld Strength Parameters for Shipbuilding"	80
SR-1249,	"Radiography Guidelines for Secondary Members"	81
SR-1250,	"Significance and Control of Lamellar Tearing of Steel Plate in the Shipbuilding Industry"	82
SR-1251,	"Evaluation of Liquid Dynamic Loads in Slack Cargo Tanks"	83
SR-1254,	"Fatigue Considerations in View of Measured Load Spectra"	84
SR-1255,	"Nondestructive Inspection of Heavy Section Castings, Forgings, and Weldments"	85

<u>SR-NO.</u>	<u>PROJECT TITLE</u>	<u>PAGE</u>	<u>PAGE</u>
SR-1256,	"Investigation of Steels for Improved Weldability in Ship Construction"	86	
SR-1257,	"Fatigue Characterization of Fabricated Ship Details"	87	
SR-1258,	"Structural Details Failure Survey Continuation"	88	
SR-1259,	"A Long-Range Research Program in Ship Structures"	89	
SR-1261,	"Hull Structural Damping Data"	90	
SR-1262,	"Ultimate Strength of Ship Hull Girder"	91	
SR-1263,	"Ship Structural Design Concepts - Part II"	92	
SR-1265,	"Evaluation of Fracture Criteria for Ship Steels and Weldments"	93	

PROJECT NO: SR-1215  
PROJECT TITLE SL-7 EXTREME STRESS DATA COLLECTION  
INVESTIGATOR: Mr. F. C. Bailey, Mr. R. Boentgen  
CONTRACTOR: Teledyne Engineering Services  
ACTIVATION DATE: September 27, 1972  
CONTRACT FUNDING: \$78,302  
SSC LONG-RANGE GOAL: Verification

#### OBJECTIVE

The objective of this study is to find the extreme stresses experienced by a single vessel in its lifetime by instrumenting eight SL-7 containerships with inexpensive, mechanical strain gages, for a period of years.

#### STATUS

Records have been continuously collected from eight SL-7 containerships through the fifth year of their operations. These records are now being analyzed under project SR-1245, "Reduction of SL-7 Scratch Gage Data."

An additional two years of data collection are being recommended.

PROJECT NO: SR-1222  
PROJECT TITLE: MATERIALS TRADE-OFF STUDY  
INVESTIGATOR: Mr. C. R. Jordan  
CONTRACTOR: Newport News Shipbuilding & Dry  
Dock Company  
ACTIVATION DATE: March 1977  
CONTRACT FUNDING: \$46,114  
SSC LONG-RANGE GOAL: Materials Criteria

#### OBJECTIVE

The objective of this study is to examine the potential for the application of modern unconventional materials to advanced ship types, unique operations, and special capabilities.

#### STATUS

A mathematical model is being developed that can synthesize a series of ship designs using any proposed material. However, in this study, the comparisons will be only between aluminum and steel. The model is to include the economic effects of such things as ship life, construction costs, repair and maintenance costs. One-time costs for machinery and equipment will be omitted from the model.

Four items of work remain to be finished: 1) tabulating data for a specific ship, 2) completing the final logic model, 3) performing a sample calculation, and 4) writing the final report. A sample calculation will be included in the final report to show the amount, type and format of data needed to permit evaluation of any proposed material in any ship configuration, as well as demonstrating the methodology.

PROJECT NO: SR-1227  
PROJECT TITLE: LOAD CRITERIA APPLICATION  
INVESTIGATOR: Mr. N.M. Maniar  
CONTRACTOR: M. Rosenblatt & Son, Inc.  
ACTIVATION DATE: April 19, 1975  
CONTRACT FUNDING: \$57,623  
SSC LONG-RANGE GOAL: Load Criteria

#### OBJECTIVE

The objective of this study is to conduct a study of statistically based load predictions of a containership, a large tanker, and a dry-bulk carrier for which actual stress records and service repair histories are available and to compare the results with the prediction methods presented in SSC-240, Load Criteria for Ship Structural Design.

#### STATUS

Additional work has been undertaken to augment the draft final report submitted in October 1976, which concluded that the dynamic increment to stress did not appear to have either a Rayleigh or an exponential distribution and further questioned whether wave-induced bending moment over the short term has a Rayleigh distribution.

Investigations are in progress to determine the statistical aspects of the vibratory stress of the SL-7 and the FONTINI-L. Also, considerable work has been accomplished to determine whether the maxima and minima of the wave-induced bending moments of the SL-7 fit the Longuet-Higgins distribution.

PROJECT NO: SR-1236  
PROJECT TITLE: SL-7 STRESS CALCULATIONS COMPARED WITH  
FULL-SCALE MEASURED VALUES  
INVESTIGATOR: Dr. H. Y. Jan  
CONTRACTOR: American Bureau of Shipping  
ACTIVATION DATE: December 9, 1976  
CONTRACT FUNDING: SSC-\$81,033; ABS-\$150, 491  
SSC LONG-RANGE GOAL: Verification

#### OBJECTIVE

The objective of the study is to compare calculated stresses to those measured on the SL-7 in corresponding sea and load conditions and to evaluate the results through each of four different and progressively more severe technical conditions.

#### STATUS

Task I, compared the static balance calculation with the full-scale dockside calibration results and found acceptable agreement with the results.

Task II is still underway calculating stress spectra and making comparisons with selected full-scale at-sea stress spectra.

Task III has compared calculated results with full-scale measurements, using measured acceleration and a specific, selected wave profile for head-sea conditions.

Task IV is a similar calculation to task III for "non-head" sea conditions, but results to date indicate that task IV cannot be completed with the present computer program.

PROJECT NO: SR-1237  
PROJECT TITLE: CRITICAL EVALUATION OF LOW-ENERGY  
COLLISION DAMAGE THEORIES AND  
DESIGN METHODOLOGIES  
INVESTIGATOR: Dr. Paul Van Mater, Jr.  
CONTRACTOR: Giannotti & Buck Associates, Inc..  
ACTIVATION DATE: February 28, 1977  
CONTRACT FUNDING: \$33,879  
SSC LONG-RANGE GOAL: Design Methods

#### OBJECTIVE

The objective is to make recommendations for the use of current methods of structural analysis in the development of low-energy collision damage theories and design methodologies and to point out the limits to their use by a critical evaluation of present practice in applicable structural analyses.

#### STATUS

Examination of collision data on 538 ships for verification of the damage theories has proven fruitless because of lack of relevant information. Work to date supports the Rosenblatt low-energy collision design methodology. The basic assumptions in that theory and a finite element method of analysis being developed by P. Y. Chang of Hydronautics, Inc. under Maritime Administration sponsorship are being further explored.

PROJECT NO: SR-1238  
PROJECT TITLE: FRACTURE TOUGHNESS CHARACTERIZATION OF  
SHIP STEEL WELDMENTS  
INVESTIGATOR: Dr. A. K. Shoemaker  
CONTRACTOR: U.S. Steel Corporation  
ACTIVATION DATE: January 28, 1977  
CONTRACT FUNDING: \$36,492  
SSC LONG-RANGE GOAL: Fabrication, Materials Criteria

#### OBJECTIVE

The objective is to determine the relevance of the Charpy V-notch energy criteria currently employed in assessing steel weldments containing fatigue cracks.

#### STATUS

None of the numerous preliminary weldments from ABS-CS plate using various combinations of consumables and heat inputs and thicknesses had a low-toughness heat-affected-zone (HAZ) necessary for this research program. After obtaining A537 plate of 1/2- and 1-inch thickness, preliminary weldments from the 1-inch plate show a low-toughness HAZ which should provide the conditions to be examined in the proposed study. Because of the time and costs incurred to establish these required weldment properties, and because of the reduced thicknesses of the A537 plate, contract modifications have been requested.

PROJECT NO: SR-1239  
PROJECT TITLE: RATIONAL LIMIT OF HULL FLEXIBILITY  
INVESTIGATOR: Dr. P. Y. Chang  
CONTRACTOR: Hydronautics, Inc.  
ACTIVATION DATE: March 31, 1977  
CONTRACT FUNDING: \$54,500  
SSC LONG-RANGE GOAL: Design Methods

### OBJECTIVE

The objective of this study is to evaluate the effect that varying ship proportions and hull materials will have on hull flexibility and on the concomitant bending and vibratory stresses.

### STATUS

The sea-state selection, vibration analysis method, choice of damping coefficients, and the four ships for study have been accepted. The method has been applied to the Great Lakes M/V CORT. Comparisons of calculated values with full-scale and model measurements are being conducted.

The other three ships to be analyzed include a 264,000 ton dead weight tanker, a C6-S-85a family of containerships, and a C4-S-69b general cargo ship.

A rationale and method for defining limits of hull flexibility have been proposed.

PROJECT NO:	SR-1240
PROJECT TITLE:	PROPELLER-INDUCED VIBRATION IN HULL STRUCTURAL ELEMENTS
INVESTIGATOR:	Dr. D.D. Kana
CONTRACTOR:	Southwest Research Institute
ACTIVATION DATE:	February 4, 1977
CONTRACT FUNDING:	\$45,965
SSC LONG-RANGE GOAL:	Design Methods

#### OBJECTIVE

The objective of this study is to recommend design procedures intended to avoid vibration problems for such structural elements as stiffened and unstiffened plate panels, deep web supporting decks, bulkheads, and the hull shell.

#### STATUS

A bibliography has been prepared, design procedures have been evaluated, and deficient areas have been identified. The proposed procedure is based on a set of methods, coupled together through a block flow diagram. However, none of the parts have been exercised for a particular ship. Arrangements are being made to do this before the final report is published.

The results will also be presented in a paper at the joint SSC-SNAME Ship Vibration Symposium '78.

PROJECT NO: SR-1241  
PROJECT TITLE: LONGITUDINAL STRENGTH CRITERIA BASED  
ON STATISTICAL DATA ANALYSIS  
INVESTIGATOR: Mr. N. S. Basar  
CONTRACTOR: M. Rosenblatt & Son, Inc.  
ACTIVATION DATE: September 30, 1976  
CONTRACT FUNDING: \$16,414  
SSC LONG-RANGE GOAL: Design Methods

#### OBJECTIVE

The objective of this study is to develop a computer program for a method for analysis of uncertainties associated with ship hull strength due to mill practices, methods of sampling, variations in material properties and scantling sizes, time-dependent effects, etc. with expressions for margins of safety and structural reliability.

#### STATUS

The uncertainties associated with ship hull strength are being quantified (to the extent possible) by coefficients of variations.

A preliminary correlation of the resulting integrated strength distribution with the available long-term wave-bending moment distribution for the "UNIVERSE IRELAND" has been attempted. Time dependent uncertainties such as damage due to corrosion and fatigue effects are being studied now.

PROJECT NO: SR-1243  
PROJECT TITLE: UNDERWATER NONDESTRUCTIVE INSPECTION  
OF WELDS  
INVESTIGATOR: Mr. C.H. Dyer  
CONTRACTOR: Naval Surface Weapons Center  
ACTIVATION DATE: December 16, 1976  
CONTRACT FUNDING: \$31,000  
SSC LONG-RANGE GOAL: Fabrication

#### OBJECTIVE

The objective of this study is to propose modifications to existing methods of nondestructive weld inspection, and to adapt them to underwater use.

#### STATUS

A literature search has been completed and people in the nondestructive testing industry have been contacted. The literature search shows that the offshore oil exploitation industry has the greatest interest in this subject and the North Sea oil industry is the most interested of these. The chief methods of inspection used are visual and tactile. Some are trying to develop magnetic particle inspection. Two examples of ultrasonic inspection of ship's hulls were found.

PROJECT NO: SR-1245  
PROJECT TITLE: REDUCTION OF SL-7 SCRATCH-GAGE DATA  
INVESTIGATOR: Mr. R. A. Fain  
CONTRACTOR: Teledyne Engineering Services  
ACTIVATION DATE: February 1977  
CONTRACT FUNDING: \$19,370  
SSC LONG-RANGE GOAL: Load Criteria, Verification

#### OBJECTIVE

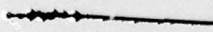
The objective is to reduce five years of scratch-gage data from eight SL-7 containerhips to usable form.

#### STATUS

The first four years of data have been examined, scaled, and presented in the following form:

- A) a histogram of stress level versus number of occurrences for each vessel for each year,
- b) a combined histogram for the vessels operating in the Atlantic and a similar plot for the vessels in Pacific service on a yearly basis, and
- c) a yearly summary histogram of all data collected from the SL-7's.

The fifth year is to be completed in 1978 and the results of all five years are to be combined in one report.



PROJECT NO: SR-1246  
PROJECT TITLE: SURVEILLANCE OF SHIP COLLISION/STRANDING  
RESEARCH STUDIES  
INVESTIGATOR: Prof. N. Jones  
CONTRACTOR: Massachusetts Institute of Technology  
ACTIVATION DATE: July 21, 1977  
CONTRACT FUNDING: \$12,934  
SSC LONG-RANGE GOAL: Information Retrieval and Dissemination

#### OBJECTIVE

The objective of this study is to identify and monitor past and current collision or stranding research and to issue status reports that will include concise discussion of new reports and new programs on related research projects.

#### STATUS

A number of groups in the U.S. and around the world interested in the ship collision problem have been contacted. Work on the structural mechanics of grounding in Japan has been completed but has not yet been released for publication.

PROJECT NO: SR-1248  
PROJECT TITLE: UPDATING OF FILLET WELD STRENGTH  
PARAMETERS FOR SHIPBUILDING  
INVESTIGATOR: Prof. K. Masubuchi  
CONTRACTOR: Massachusetts Institute of Technology  
ACTIVATION DATE: July 11, 1977  
CONTRACT FUNDING: \$30,609  
SSC LONG-RANGE GOAL: Design Methods, Fabrication

#### OBJECTIVE

The objective of this study is to recommend updated fillet weld requirements for domestic ship application by reviewing the development of current marine fillet weld requirements and available test data.

#### STATUS

This project has five tasks: 1) literature survey, 2) review of welding standards, 3) contacts with experts, 4) analysis of data, and 5) making recommendations. Tasks 1, 2, and 3 have been completed. Work is proceeding on task 4.

Tentative results indicate fillet weld sizes are conservative for static strength. Additional analysis is underway to determine size requirement for fatigue and corrosion allowances.

PROJECT NO: SR-1249  
PROJECT TITLE: RADIOGRAPHY GUIDELINES FOR SECONDARY MEMBERS  
INVESTIGATOR: Mr. E.L. Criscuolo  
CONTRACTOR: Naval Surface Weapons Center  
ACTIVATION DATE: December 16, 1976  
CONTRACT FUNDING: \$41,000  
SSC LONG-RANGE GOAL: Fabrication

#### OBJECTIVE

The objective of the study is to determine whether additional inspection guidelines are needed after ship building structural welds of webs and longitudinals have been surveyed.

#### STATUS

A search of ship casualty reports has been made. Available radiographs of ship longitudinals have been reviewed and a survey of major shipyards is nearing completion. The results of this work and specific recommendations will be incorporated into a technical report.

PROJECT NO: SR-1250  
PROJECT TITLE: SIGNIFICANCE AND CONTROL OF LAMELLAR  
TEARING OF STEEL PLATE IN THE SHIP-  
BUILDING INDUSTRY  
INVESTIGATOR: Mr. R.C. Janava  
CONTRACTOR: Gibbs & Cox  
ACTIVATION DATE: November 11, 1977  
CONTRACT FUNDING: \$11,154  
SSC LONG-RANGE GOAL: Design Methods, Materials Criteria,  
Fabrication

#### OBJECTIVE

The objective of this study is to prepare a document containing reasonable guidelines, welding procedures, and testing methods to prevent lamellar tearing in ship structures using steels up to 100 ksi yield strength range.

#### STATUS

The document is being prepared.

PROJECT NO: SR-1251  
PROJECT TITLE: EVALUATION OF LIQUID DYNAMIC LOADS  
IN SLACK CARGO TANKS  
INVESTIGATOR: Dr. R.L. Bass  
CONTRACTOR: Southwest Research Institute  
ACTIVATION DATE: September 16, 1977  
CONTRACT FUNDING: \$72,159  
SSC LONG-RANGE GOAL: Load Criteria, Verification

#### OBJECTIVE

The objective of this study is to survey, test, analyze, and develop liquid dynamic load criteria in slack cargo tanks.

#### STATUS

Work has begun on the data review and evaluation.

These phases will follow:

- Establish structural design particulars for all LNG tank designs.
- Identify data necessary to develop design methods.
- Conduct additional experimental tests to supplement current slosh loads data.
- Conduct experimental tests to determine structural response of LNG membrane tank structures.
- Generate simplified tank design curves for predicting tank loads as a function of geometry, amplitude, frequency, and fill depth.
- Develop pressure-time histories for impulse slosh loadings in full scale.
- Use analytical methods to predict tank wall response to impulse loadings.
- Generate design curves showing worst case peak pressure magnitudes and the time variations over which they act.
- Develop simplified procedures to include LNG slosh loads in the design of an LNG ship tank and its supports.

PROJECT NO: SR-1254  
PROJECT TITLE: FATIGUE CONSIDERATIONS IN VIEW OF  
MEASURED LOAD SPECTRA  
INVESTIGATOR: Unknown  
CONTRACTOR: Unknown  
ACTIVATION DATE: Unknown  
CONTRACT FUNDING: Unknown  
SSC LONG-RANGE GOAL: Materials Criteria, Design Methods

### OBJECTIVE

The objective of this study is to assess the influence of fatigue loading spectra on the margin of safety provided by current fatigue design practices.

### STATUS

Proposals have been evaluated and contract negotiations are underway.

PROJECT NO: SR-1255  
PROJECT TITLE: NONDESTRUCTIVE INSPECTION OF HEAVY  
SECTION CASTINGS, FORGINGS, AND  
WELDMENTS  
INVESTIGATOR: Mr. E.L. Criscuolo  
CONTRACTOR: Naval Surface Weapons Center  
ACTIVATION DATE: June 1, 1977  
CONTRACT FUNDING: \$20,000  
SSC LONG-RANGE GOAL: Fabrication

#### OBJECTIVE

The objective of this study is to survey representative nondestructive inspection methods for ship castings, forgings, and weldments, and attempt to determine existing quantitative acceptance standards.

#### STATUS

Procedural guidelines and recommended methods for controlling quality of castings and forgings as set forth by the major technical societies are being reviewed.

PROJECT NO: SR-1256  
PROJECT TITLE: INVESTIGATION OF STEELS FOR IMPROVED  
WELDABILITY IN SHIP CONSTRUCTION  
INVESTIGATOR: Unknown  
CONTRACTOR: Unknown  
ACTIVATION DATE: Unknown  
CONTRACT FUNDING: Unknown  
SSC LONG-RANGE GOAL: Materials Criteria, Fabrication

#### OBJECTIVE

The objective of this study is to select the optimum materials, processes, and weld treatments to provide adequate service life by using fracture and fatigue control tests.

#### STATUS

Proposals were technically evaluated February 9, 1978.

PROJECT NO: SR-1257  
PROJECT TITLE: FATIGUE CHARACTERIZATION OF FABRICATED  
SHIP DETAILS  
INVESTIGATOR: Unknown  
CONTRACTOR: Unknown  
ACTIVATION DATE: Unknown  
CONTRACT FUNDING: Unknown  
SSC LONG-RANGE GOAL: Fabrication, Load Criteria

#### OBJECTIVE

The objective of this study is to classify ship details in terms of their behavior and useful life under cyclic-loading conditions.

#### STATUS

Proposals were technically evaluated January 25, 1978.

PROJECT NO: SR-1258  
PROJECT TITLE: STRUCTURAL DETAILS FAILURE SURVEY  
CONTINUATION  
INVESTIGATOR: Mr. C.R. Jordan  
CONTRACTOR: Newport News Dry Dock and Shipping  
Company  
ACTIVATION DATE: September 14, 1977  
CONTRACT FUNDING: \$49,761  
SSC LONG-RANGE GOAL: Design, Materials, Fabrication

#### OBJECTIVE

The objective of this study is to evaluate the effectiveness of the analyses of structural details by examining several details in selective ships undergoing repairs or periodic surveys.

#### STATUS

Surveys are being made of 12 bulk carriers, 12 general cargo ships, and 12 containerships, concentrating on the midship cargo sections, to augment the data obtained in Project SR-1232, "Structural Details Failure Survey."

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REVIEW AND RECOMMENDATIONS FOR THE INTERAGENCY SHIP STRUCTURE C--ETC(U)  
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PROJECT NO: SR-1259  
PROJECT TITLE: A LONG-RANGE RESEARCH PROGRAM IN SHIP  
STRUCTURES  
INVESTIGATOR: Unknown  
CONTRACTOR: Unknown  
ACTIVATION DATE: Unknown  
CONTRACT FUNDING: Unknown  
SSC LONG-RANGE GOAL: All of them

#### OBJECTIVE

The objective of this study is to develop a ship structures planning document directed toward, but not be limited to, the technical goals and charter of the Ship Structure Committee, and to forecast the research and development needs, based on a system of priorities, for the next 20 years.

#### STATUS

A request for proposals has been issued.

PROJECT NO: SR-1261  
PROJECT TITLE: HULL STRUCTURAL DAMPING DATA  
INVESTIGATOR: Unknown  
CONTRACTOR: Unknown  
ACTIVATION DATE: Unknown  
CONTRACT FUNDING: Unknown  
SSC LONG-RANGE GOAL: Design Methods

#### OBJECTIVE

The objective of this study is to collect and evaluate structural damping data applicable to ship vibration analysis, and to recommend an experimental program, model or full scale, to expand and verify the design data.

#### STATUS

A proposal request has been prepared.

PROJECT NO: SR-1262  
PROJECT TITLE: ULTIMATE STRENGTH OF SHIP HULL GIRDER  
INVESTIGATOR: Unknown  
CONTRACTOR: Unknown  
ACTIVATION DATE: Unknown  
CONTRACT FUNDING: Unknown  
SSC LONG-RANGE GOAL: Design Methods

#### OBJECTIVE

The objective of this study is to develop a procedure to determine the load-deformation characteristics and ultimate strength of a ship hull girder under various combinations of vertical, lateral, and torsional loads.

#### STATUS

Proposals have been evaluated and contract negotiations are proceeding.

PROJECT NO: SR-1263  
PROJECT TITLE: SHIP STRUCTURAL DESIGN CONCEPTS  
- PART II  
INVESTIGATOR: Dr. J.H. Evans  
CONTRACTOR: J.H. Evans  
ACTIVATION DATE: Unknown  
CONTRACT FUNDING: Unknown  
SSC LONG-RANGE GOAL: Design Methods

#### OBJECTIVE

The objective of this study is to prepare a supplementary monograph to the Ship Structural Design Concepts published in 1974.

#### STATUS

A sole source proposal has been received.

PROJECT NO: SR-1265  
PROJECT TITLE: EVALUATION OF FRACTURE CRITERIA FOR  
SHIP STEELS AND WELDMENTS  
INVESTIGATOR: Unknown  
CONTRACTOR: Unknown  
ACTIVATION DATE: Unknown  
CONTRACT FUNDING: Unknown  
SSC LONG-RANGE GOAL: Materials Criteria

#### OBJECTIVE

The objective of this study is to prepare a state-of-the-art interpretation report on the correlation of fracture toughness in ship steels and weldments to proposed criteria for adequate resistance to fracture in service.

#### STATUS

A prospectus has been prepared.

**NOTES**

PROJECT NO: 100-100000  
 PROJECT TITLE: INVESTIGATION OF FRACTURE CRITERIA FOR  
 SHIP STEELS AND WELDS  
 INVESTIGATOR: UNKNOWN  
 CONTRACTOR: UNKNOWN  
 ACTIVATION DATE: UNKNOWN  
 CONTRACT NUMBER: UNKNOWN  
 SEE LONG-RANGE GOAL: Materials Criteria

**OBJECTIVE**

The objective of this study is to prepare a state-of-the-art interpretation report on the correlation of fracture toughness in ship steels and weldments to proposed criteria for adequate resistance to fracture in service.

**STATUS**

A prospectus has been prepared.

### REVIEW OF COMPLETED PROJECTS IN 1977

Table IV below lists those projects that have been completed in fiscal year 1978. Project descriptions, similar to those for the active program, follow. Reports from these projects have either been published or are presently in the publication process and the final SSC reports can be expected in the near future.

### TABLE V - A LIST OF PROJECTS COMPLETED IN 1978

- SR-1221, "Correlation and Verification of Wavemeter Data From SL-7"
- SR-1224, "Fracture Criteria"
- SR-1231, "Fracture Criteria Based on Loading Rates"
- SR-1232, "Structural Details Failure Survey"
- SR-1235, "Full-Scale Slam Investigation"
- SR-1247, "Critical Analysis of Ship Structural Casualty Data"

PROJECT NO: SR-1221  
PROJECT TITLE: CORRELATION AND VERIFICATION OF  
WAVEMETER DATA FROM SL-7  
INVESTIGATOR: Mr. J. Dalzell  
CONTRACTOR: Stevens Institute of Technology  
ACTIVATION DATE: June 14, 1974  
CONTRACT FUNDING: \$84,990  
SSC LONG-RANGE GOAL: Verification

#### OBJECTIVE

The objectives of this study are:

- 1) to reduce three winter season's wavemeter data obtained in the SL-7 containership instrumentation project,
- 2) to verify and measure the capability of each of the wavemeter systems provided,
- 3) to compare their performance, and
- 4) to investigate the correlation of the individual system signals with ship motions and/or strain measurements.

#### RESULTS

Technically, the comparisons suggest that the radar wave measurements are too high and the Tucker meter wave measurements too low. Quantitatively, if the Tucker data are correct, both model test data as well as contemporary theory for wave-induced bending moments have to be in error by a factor of about three. If it can be agreed that contemporary theory and model test techniques are better than this, the evidence suggests that the radar systems, despite its known deficiencies, is closer to reality.

A list of recommendations on improving both systems is being implemented by the Coast Guard.

PROJECT NO: SR-1224  
PROJECT TITLE: FRACTURE CRITERIA  
INVESTIGATOR: Dr. P. Francis  
CONTRACTOR: Southwest Research Institute  
ACTIVATION DATE: May 19, 1975  
CONTRACT FUNDING: \$71,222  
SSC LONG-RANGE GOAL: Materials Criteria

#### OBJECTIVE

The objective is to characterize the nil-ductility temperatures and dynamic tear energies of candidate ship steels and weldments up to 100,000 psi yield strengths for comparison with the suggested fracture criteria in SSC-244, Fracture Control Guidelines for Welded Steel Ship Hulls.

#### RESULTS

A series of tests were performed on seven grades of ship steel that covered the range of ordinary as-rolled, to high-strength quenched and tempered alloy's, namely: ABS-B, CS, AH-32, EH-32, ASTM A517-D, A678-C, and A-537B. The results from this project and that of SR-1231, "Fracture Criteria Based on Loading Rates" will be used in project SR-1265, "Evaluation of Fracture Criteria for Ship Steel Weldments."

PROJECT NO:	SR-1231
PROJECT TITLE:	FRACTURE CRITERIA BASED ON LOADING RATES
INVESTIGATOR:	Dr. P. Francis
CONTRACTOR:	Southwest Research Institute
ACTIVATION DATE:	June 20, 1975
CONTRACT FUNDING:	\$48,995
SSC LONG-RANGE GOAL:	Materials Criteria

### OBJECTIVE

The objective is to delineate effects of loading rates on fracture initiation, and to provide a method to later verify the findings by realistic model tests.

### RESULTS

Yield strength and fracture toughness values were determined as a function of load rate and temperature on ABS-B, DS, AH-32, EH-32, CS, ASTM A-517D, A-678-C, and A-537B ship steels. These results will serve as input data in project SR-1265 "Evaluation of Fracture Criteria for Ship Steel Weldments."

PROJECT NO: SR-1232  
PROJECT TITLE: STRUCTURAL DETAILS FAILURE SURVEY  
INVESTIGATOR: Mr. C.R. Jordan  
CONTRACTOR: Newport News Shipbuilding & Dry Dock  
Company  
ACTIVATION DATE: January 9, 1976  
CONTRACT FUNDING: \$45,427  
SSC LONG-RANGE GOAL: Design, Materials, Fabrication

### OBJECTIVE

The objective of this study is to evaluate the effectiveness of analyses of details by examining several structural details in selected ships undergoing repairs or periodic surveys.

### RESULTS

Data on sound and failed details have been gathered from interviews, repair specifications, and all possible inspections aboard fifty ships undergoing repairs or periodic surveys in several repair yards around the country. During the survey 490,210 details with 3,307 failures were observed. Eighty-two percent of the failures were in the cargo space and were predominately located in structure adjacent to the side shell. The remaining 18 percent were distributed ten percent forward and eight percent aft of the cargo spaces.

The final report will describe the following details surveyed: beam brackets, tripping brackets, non-tight collars, tight-collars, gunwale connections, clearance cutouts, deck cutouts, miscellaneous cutouts, stanchion ends, stiffener ends, and panel stiffeners.

PROJECT NO:	SR-1235
PROJECT TITLE:	FULL-SCALE SLAM INVESTIGATION
INVESTIGATOR:	Mr. E.G.U. Band
CONTRACTOR:	Payne, Inc.
ACTIVATION DATE:	February 20, 1976
CONTRACT FUNDING:	\$63,878
SSC LONG-RANGE GOAL:	Load Criteria

#### OBJECTIVE

The objective of this study is to investigate the correlation of slamming impact pressures, generated full-scale on the forward bottom structure and bow-flare structure of merchant ship hull forms, with corresponding impact pressures measured at model scale, then to develop instrumentation to obtain full-scale slamming data, and to plan a model and full-scale testing program for correlation of the test results.

#### RESULTS

The instrumentation package was demonstrated but reservations persist about the ability of the proposed modified Collins Radar Altimeter to provide the required relative velocity measurements. The Coast Guard is now planning to use the Collins Radar Altimeter on their Great Lakes project to provide additional data in conjunction with other wave-measuring devices.

PROJECT NO: SR-1247  
PROJECT TITLE: CRITICAL ANALYSIS OF SHIP STRUCTURAL  
CASUALTY DATA  
INVESTIGATOR: Mr. J.C. Daidola  
CONTRACTOR: M. Rosenblatt & Son, Inc.  
ACTIVATION DATE: August 23, 1976  
CONTRACT FUNDING: \$12,050  
SSC LONG-RANGE GOAL: Load Criteria, Design Methods,  
Fabrication

### OBJECTIVE

The objective of this study is to develop a list of sources of existing ship damage data, to develop a method for the analysis of the data, and to develop procedures for establishing research priorities with a view toward minimizing losses from ship damage.

### RESULTS

A limited evaluation of the feasibility of conducting a more in-depth study was performed. No source was found containing sufficient data to set priorities for research, or for detailed structural analyses. This lack has been corroborated by the investigators for project SR-1237, "Critical Evaluation of Low-Energy Collision Damage Theories and Design Methodologies."

The report has been placed in the National Technical Information Service.

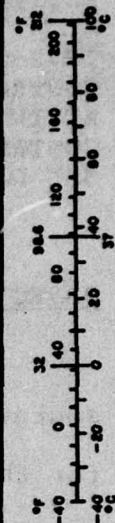
# METRIC CONVERSION FACTORS

## Approximate Conversions to Metric Measures

Symbol	When You Know	Multiply by	To Find	Symbol
<b>LENGTH</b>				
in	inches	2.5	centimeters	cm
ft	feet	30	centimeters	cm
yd	yards	0.9	meters	m
mi	miles	1.6	kilometers	km
<b>AREA</b>				
sq in	square inches	6.5	square centimeters	cm <sup>2</sup>
sq ft	square feet	0.09	square meters	m <sup>2</sup>
sq yd	square yards	0.8	square meters	m <sup>2</sup>
sq mi	square miles	2.6	square kilometers	km <sup>2</sup>
acres	acres	0.4	hectares	ha
<b>MASS (weight)</b>				
oz	ounces	28	grams	g
lb	pounds	0.45	kilograms	kg
	short tons (2000 lb)	0.9	tonnes	t
<b>VOLUME</b>				
cup	cup	0.24	milliliters	ml
pt	pint	0.47	milliliters	ml
qt	quart	0.95	liters	l
gal	gallon	3.8	liters	l
cu ft	cubic feet	0.03	cubic meters	m <sup>3</sup>
cu yd	cubic yards	0.76	cubic meters	m <sup>3</sup>
<b>TEMPERATURE (exact)</b>				
°F	Fahrenheit temperature	5/9 (after subtracting 32)	Celsius temperature	°C

\* 1 in = 2.54 exactly. For other exact conversions and more detailed tables, see NBS Spec. Publ. 280, Guide for Heights and Masses, NIST 12.2, 80 Catalog No. C12.10-280.

Symbol	When You Know	Multiply by	To Find	Symbol
<b>LENGTH</b>				
mm	millimeters	0.04	inches	in
cm	centimeters	0.4	inches	in
m	meters	3.3	feet	ft
km	kilometers	1.1	yards	yd
		0.5	miles	mi
<b>AREA</b>				
cm <sup>2</sup>	square centimeters	0.16	square inches	in <sup>2</sup>
m <sup>2</sup>	square meters	1.2	square yards	yd <sup>2</sup>
ha	square kilometers	0.4	square miles	mi <sup>2</sup>
km <sup>2</sup>	hectares (10,000 m <sup>2</sup> )	2.5	acres	ac
<b>MASS (weight)</b>				
g	grams	0.035	ounces	oz
kg	kilograms	2.2	pounds	lb
t	tonnes (1000 kg)	1.1	short tons	st
<b>VOLUME</b>				
ml	milliliters	0.03	fluid ounces	fl oz
l	liters	2.1	pints	pt
		1.06	quarts	qt
m <sup>3</sup>	cubic meters	0.26	gallons	gal
		36	cubic feet	cu ft
		1.3	cubic yards	cu yd
<b>TEMPERATURE (exact)</b>				
°C	Celsius temperature	9/5 (then add 32)	Fahrenheit temperature	°F



1. Report No.	2. Government Accession N.	3. Recipient's Catalog No.	
4. Title and Subtitle <b>REVIEW AND RECOMMENDATIONS FOR THE INTERAGENCY SHIP STRUCTURE COMMITTEE'S FISCAL 1979 RESEARCH PROGRAM</b>		5. Report Date <b>March, 1978</b>	
		6. Performing Organization Code	
		8. Performing Organization Report No.	
7. Author(s) <b>Ship Research Committee</b>		10. Work Unit No. (TRAIS)	
9. Performing Organization Name and Address <b>Ship Research Committee National Academy of Sciences 2101 Constitution Avenue, Washington, D.C. 20418</b>		11. Contract or Grant No. <b>DOT-CG-<del>20387</del> A</b>	
		13. Type of Report <b>80356-1A</b> <b>Final Report</b>	
12. Sponsoring Agency Name and Address <b>Commandant (G-DST) U.S. Coast Guard Headquarters Office of Research and Development Washington, D.C. 20590</b>		14. Sponsoring Agency Code <b>G-DST-2</b>	
15. Supplementary Notes			
16. Abstract <p>The Ship Research Committee (SRC) of the National Research Council provides technical services covering program recommendations, proposal evaluations, and project advice to the interagency Ship Structure Committee (SSC), composed of representatives from the U.S. Coast Guard, Naval Sea Systems Command, Military Sealift Command, Maritime Administration, and the American Bureau of Shipping. This arrangement, established since 1946, requires continuing interaction among the SRC, the SSC, the contracting agency and the project investigators to assure an effective program to improve ship hull structures through an extension of knowledge of materials, fabrication methods, static and dynamic loading and response, and methods of analysis and design. This report contains the Ship Research Committee's recommended research program for five years, FY 1978 - 1982, with 14 specific prospectuses from which to select projects for FY 1979. Also included is a brief review of 26 active and 6 recently completed projects.</p>			
17. Key Words		18. Distribution Statement <b>Document is available to the public through the National Technical Information Service, Springfield, VA 22161</b>	
19. Security Classif. (of this report) <b>Unclassified</b>	20. Security Classif. (of this page) <b>Unclassified</b>	21. No. of Pages <b>101</b>	22. Price

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